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Wakabayashi et al.

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(54) ULTRASOUND TRANSDUCER ARRAY

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(73) Assignee: **Olympus Optical Co., Ltd.** (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

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(22) Filed: **Nov. 30, 2001**

(65) **Prior Publication Data**

US 2002/0156373 A1 Oct. 24, 2002

(30) **Foreign Application Priority Data**

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Jan. 30, 2001	(JP)	2001-022202
Feb. 20, 2001	(JP)	2001-043785

(51) **Int. Cl.**[7] **A61B 8/00**
(52) **U.S. Cl.** **600/437**; 600/457
(58) **Field of Search** 600/437, 443, 600/459, 462, 463; 73/642; 204/197

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English translation of Abstract of Japanese Patent No. 56–091201 dated Jul. 24, 1981.
English translation of Japanese Gazette Scope of Claim for Patent No. Shō 62–2813 dated Jan. 21, 1987.

Primary Examiner—Francis J. Jaworski
Assistant Examiner—Maulin Patel
(74) *Attorney, Agent, or Firm*—Ostrolenk, Faber, Gerb & Soffen, LLP

(57) **ABSTRACT**

By bonding a conductive first matching layer **14** to the acoustic radiation surface side, which is the bottom side, of a belt-shape piezoelectric element on both faces with electrodes provided, and using a dicing machine to form divided grooves **16**, an array of piezoelectric elements **6, 6, . . . , 6** is formed in the element array direction. By deepening the divided grooves **16**, generation of cross talk can be prevented, and by filling the portions of the divided grooves **16** not in contact with the piezoelectric elements **6** with a conductive adhesive **17**, a reduction in strength due to formation of the divided grooves **16** can be prevented, and a common connection between the ground electrode **13*b*** on the bottom surface of each piezoelectric element **6** and the conductive first matching layer **14** can be reliably secured.

22 Claims, 18 Drawing Sheets

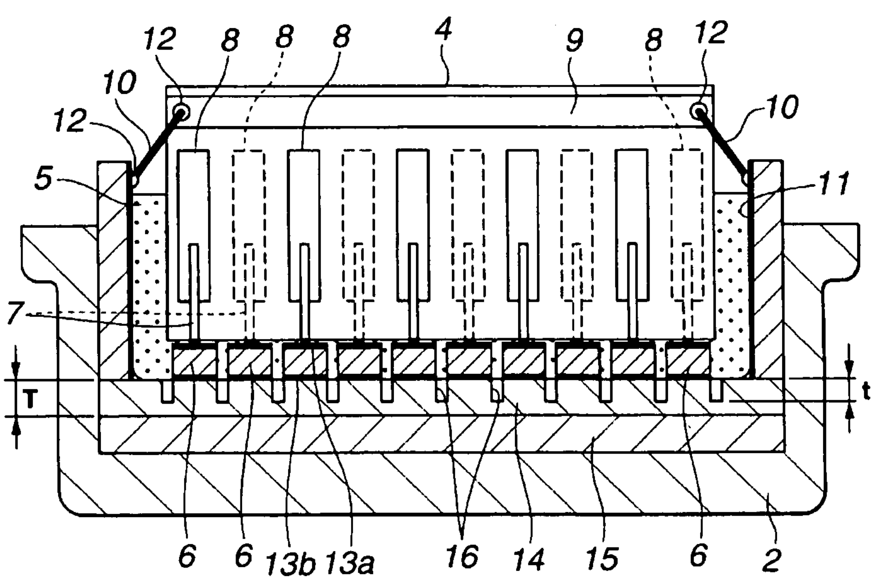


FIG.1

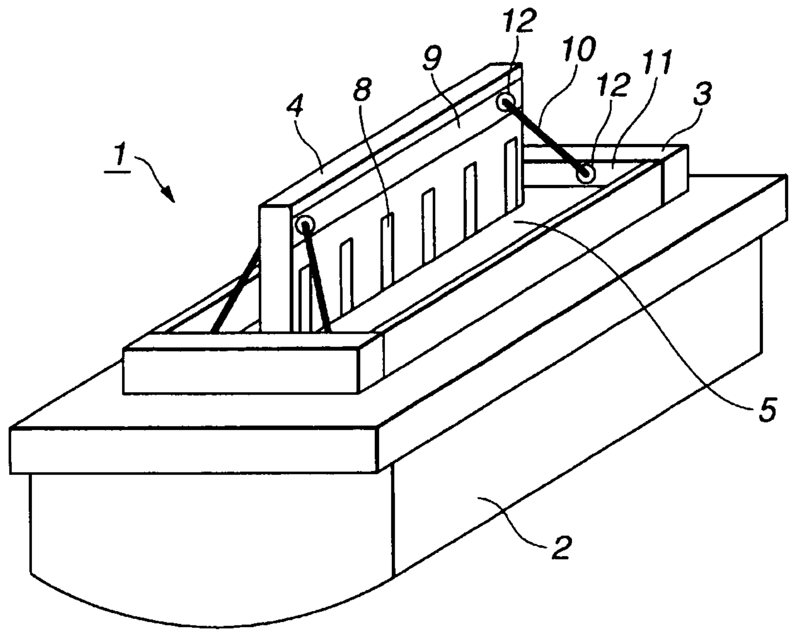
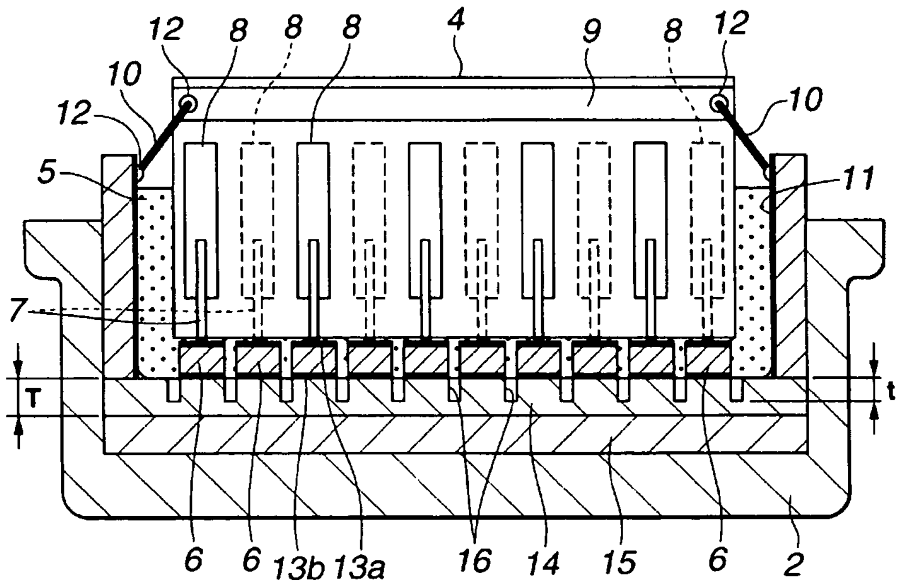

12
10
12
11
3
9
4
8
1
5
2

FIG.2


12
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4
9
8
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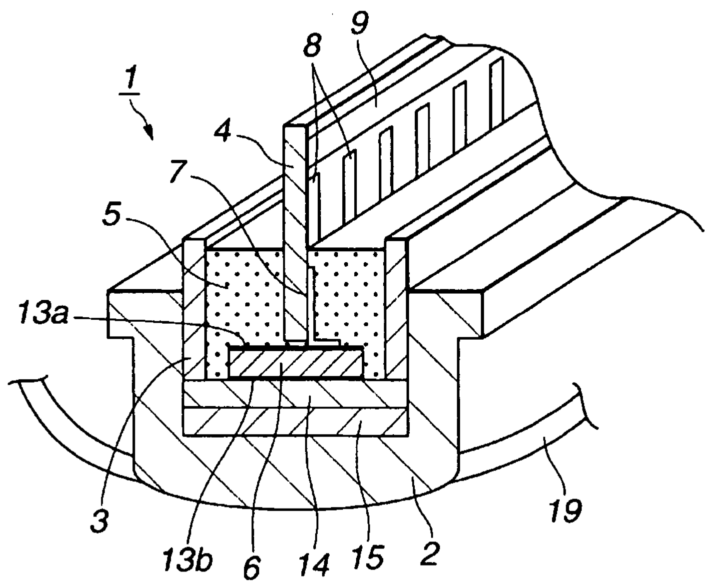
11
7
T
t
6
6
13b
13a
16
14
15
6
2

FIG.3


1
9
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7
5
13a
3
13b
6
14
15
2
19

FIG.4

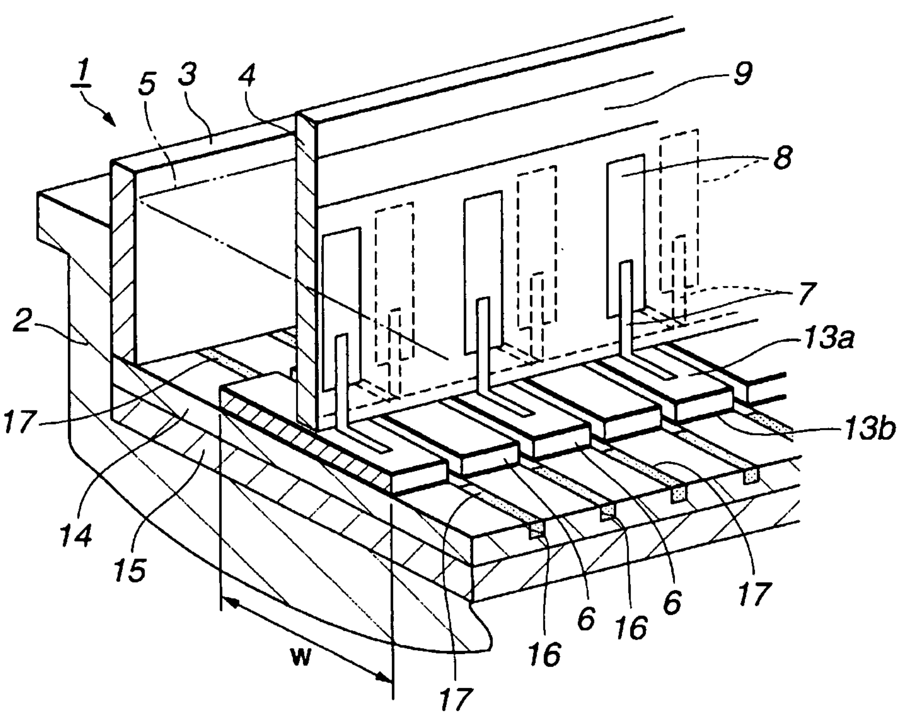

1
5
3
4
9
8
7
13a
2
17
13b
14
15
6
16
6
17
16
16
W
17

FIG.5

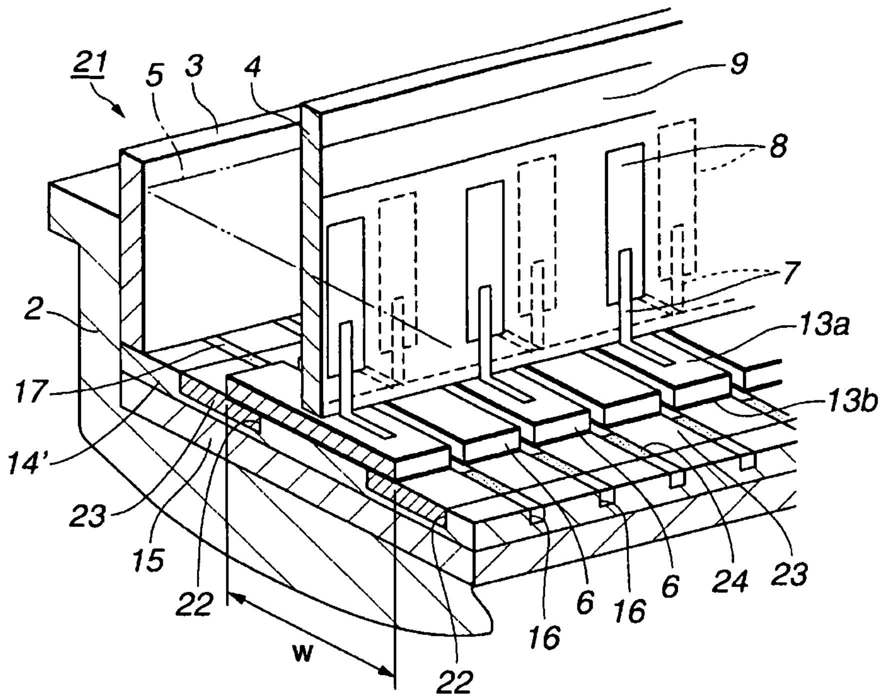

21
5
3
4
9
8
7
13a
13b
2
17
14'
23
15
22
16
6
16
6
24
23
22
w

FIG.6

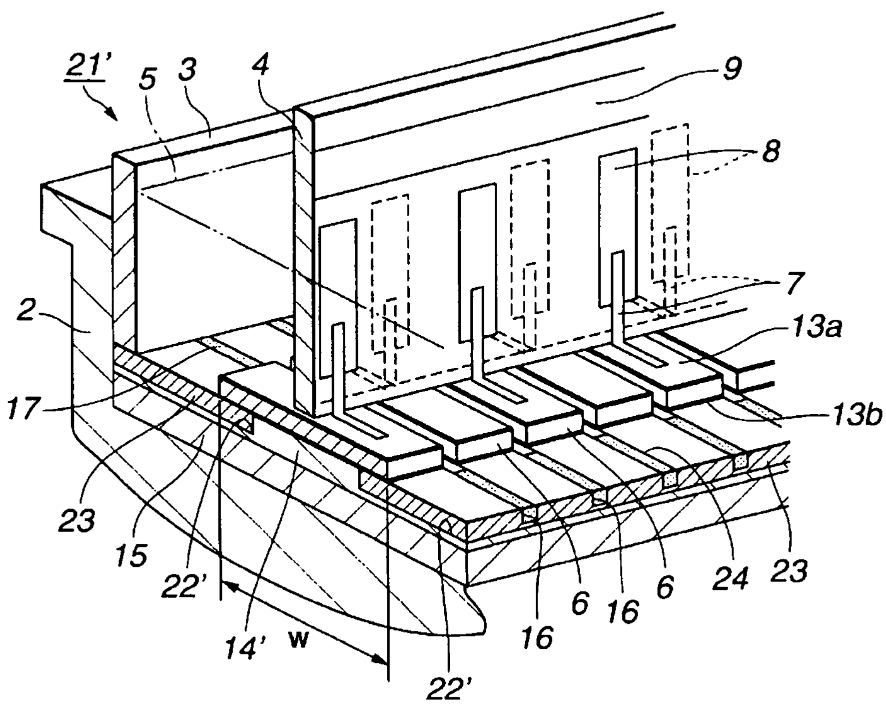

21'
5
3
4
9
8
7
13a
13b
2
17
23
15
22'
14'
w
16
6
16
6
24
23
22'

FIG.7

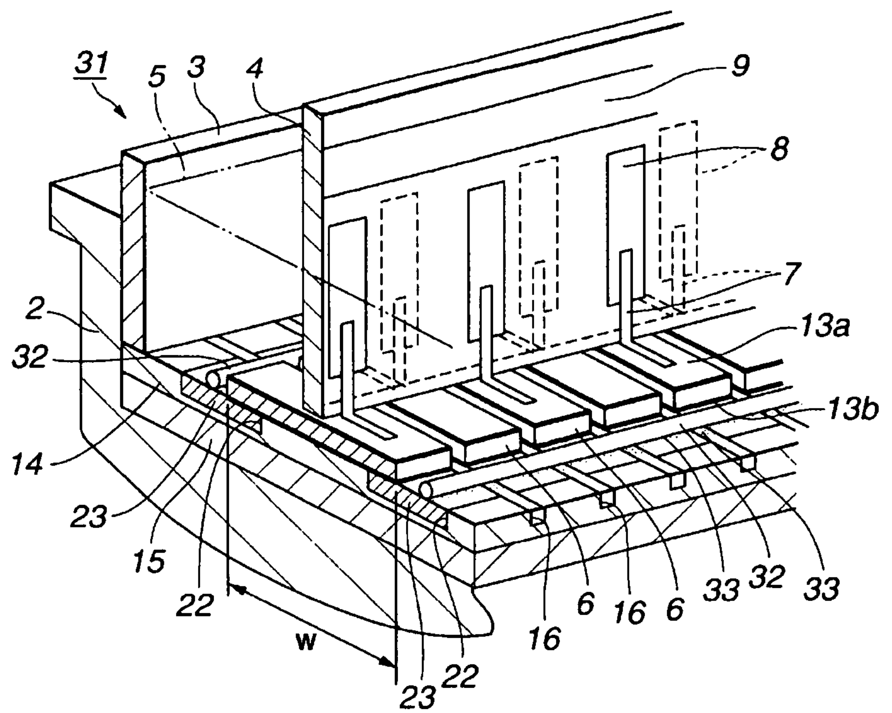

31
5
3
4
9
8
7
13a
13b
2
32
14
23
15
22
W
23
22
16
6
16
6
33
32
33

FIG.8

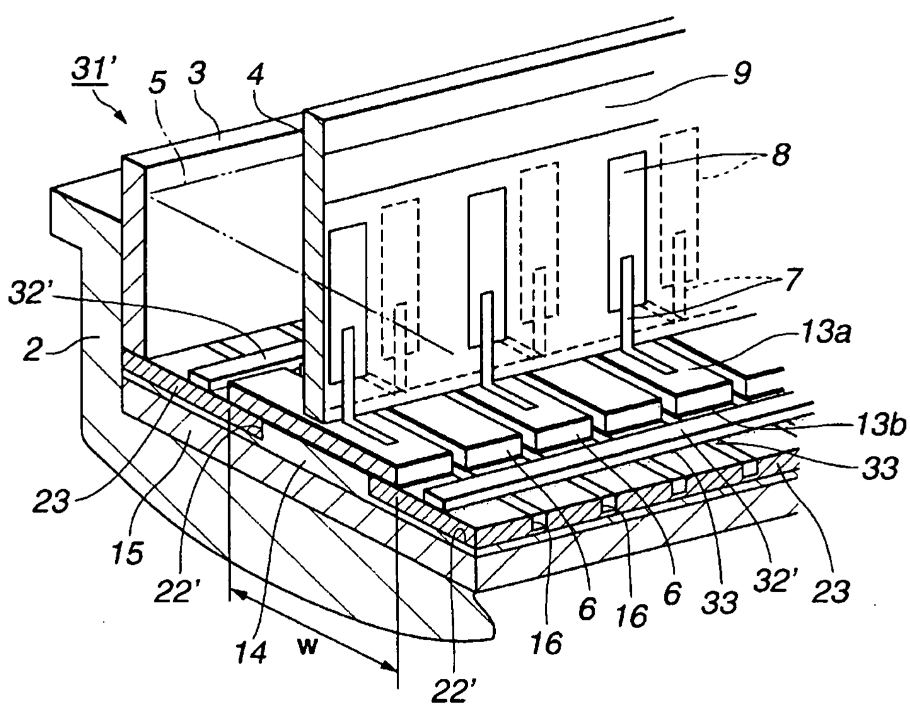

31'
5
3
4
9
8
7
13a
13b
33
32'
2
23
15
22'
14
W
22'
16
6
16
6
33
32'
23

FIG.9

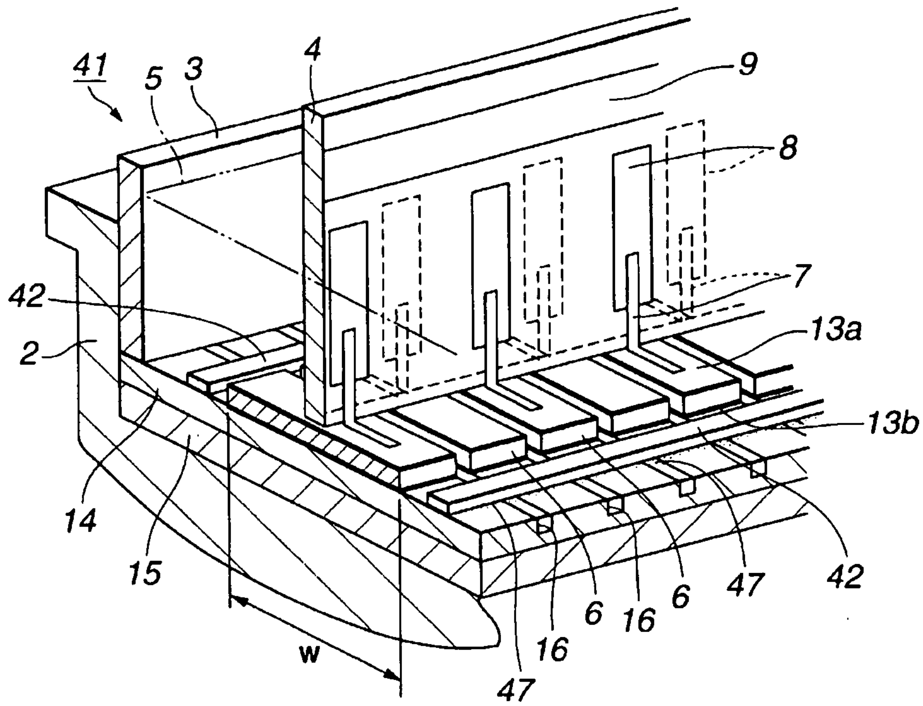

41
5
3
4
9
8
7
42
2
13a
13b
14
15
w
47
16
6
16
6
47
42
16

FIG.10

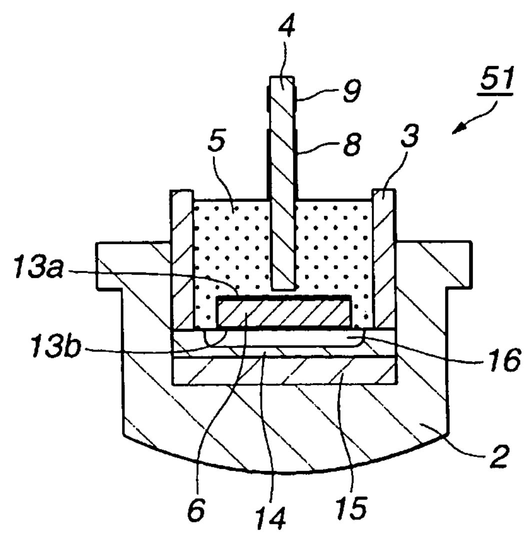

4
9
51
5
8
3
13a
13b
16
2
6
14
15

FIG.11

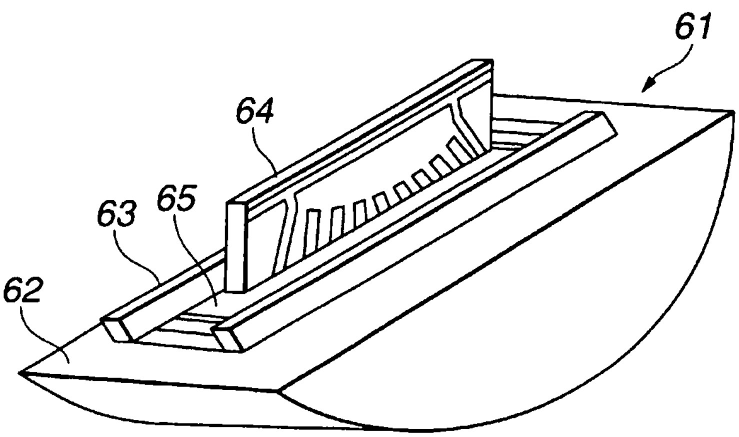


FIG.12

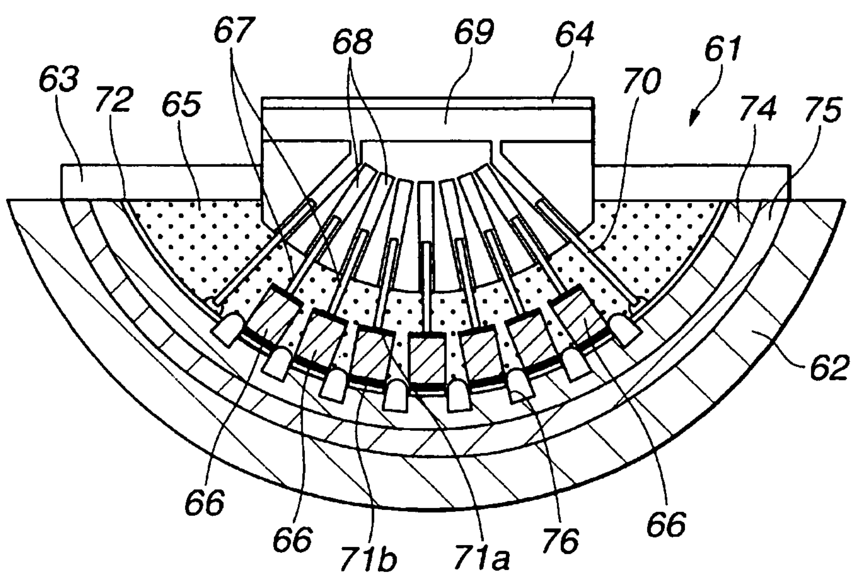
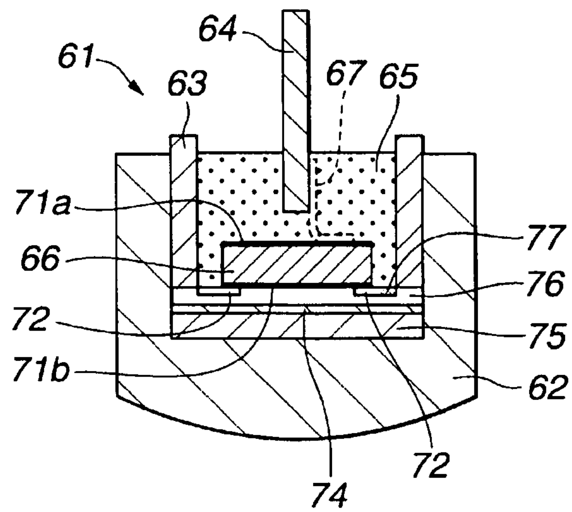
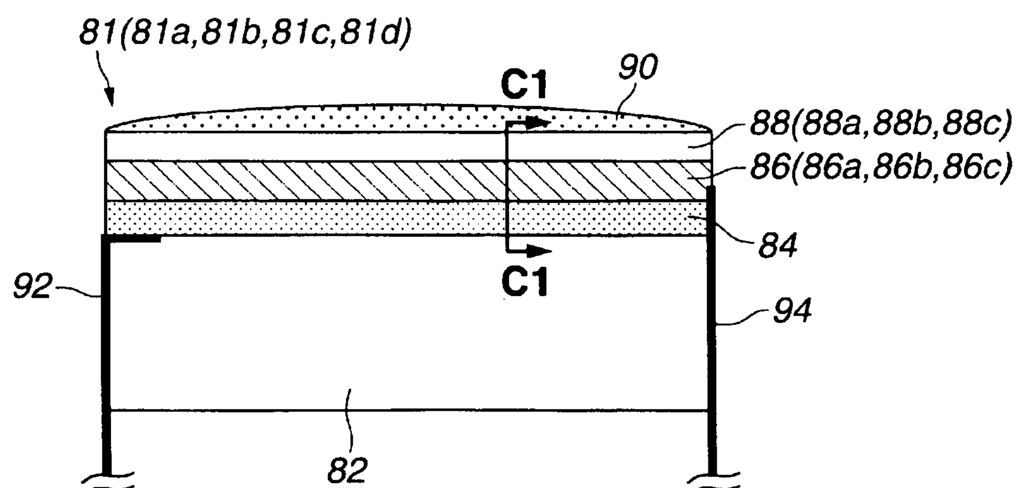


FIG.13



61
63
64
67
65
71a
66
72
71b
77
76
75
62
72
74

FIG.14



81(81a,81b,81c,81d)
C1
90
88(88a,88b,88c)
86(86a,86b,86c)
84
92
C1
94
82

FIG.15

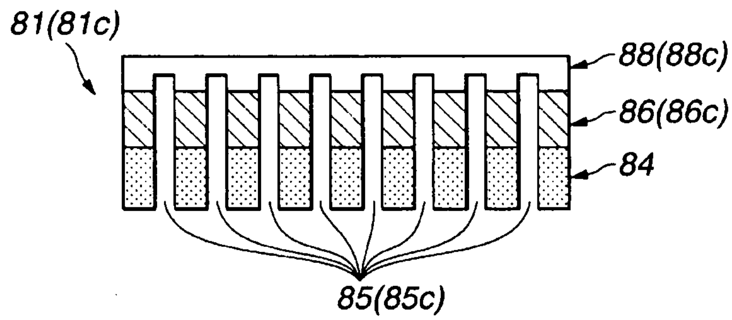


FIG.16

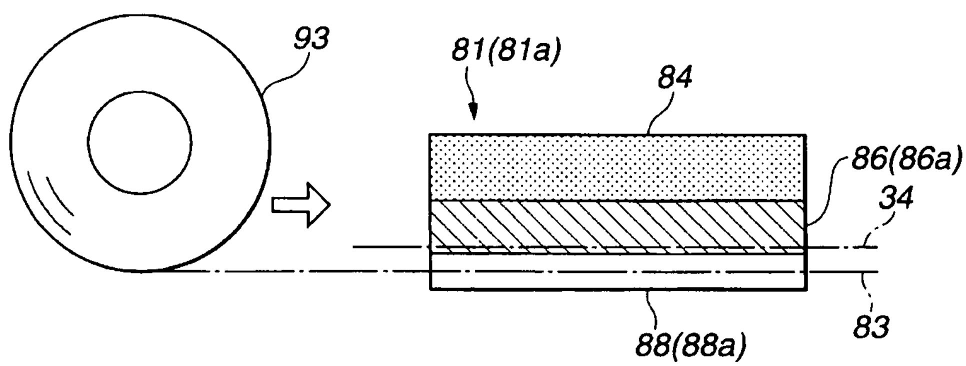


FIG.17

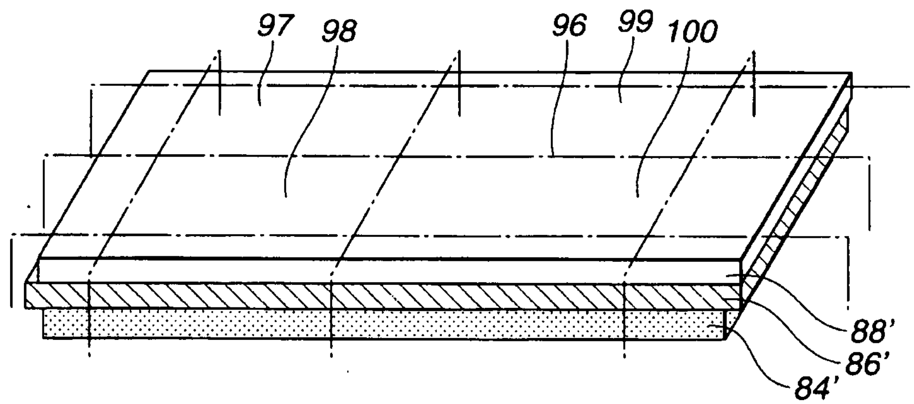


FIG.18

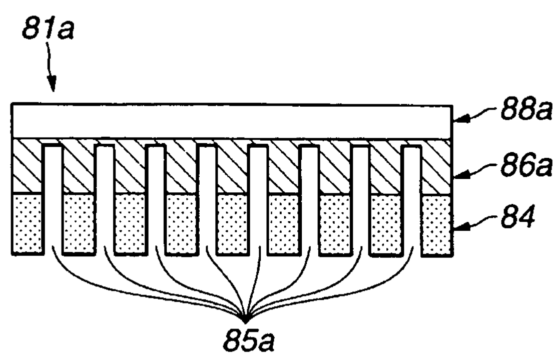


FIG.19

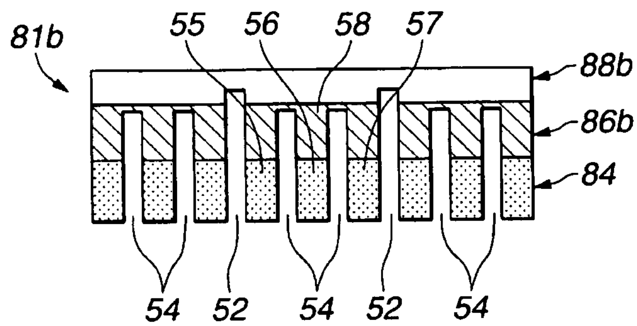

81b
55
56
58
57
88b
86b
84
54
52
54
52
54

FIG.20

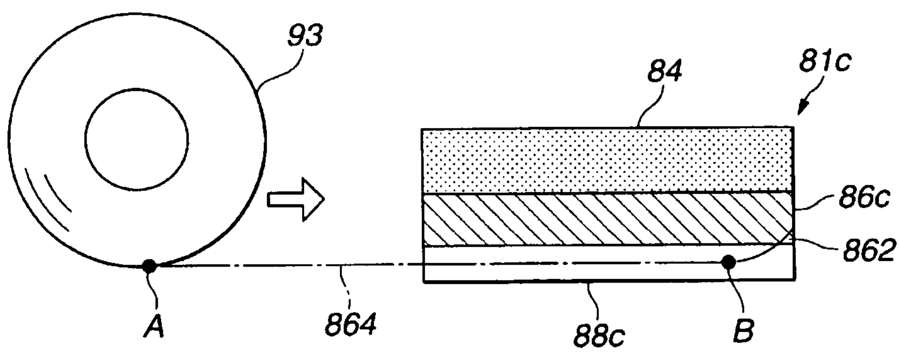

93
84
81c
86c
862
A
864
88c
B

FIG.21

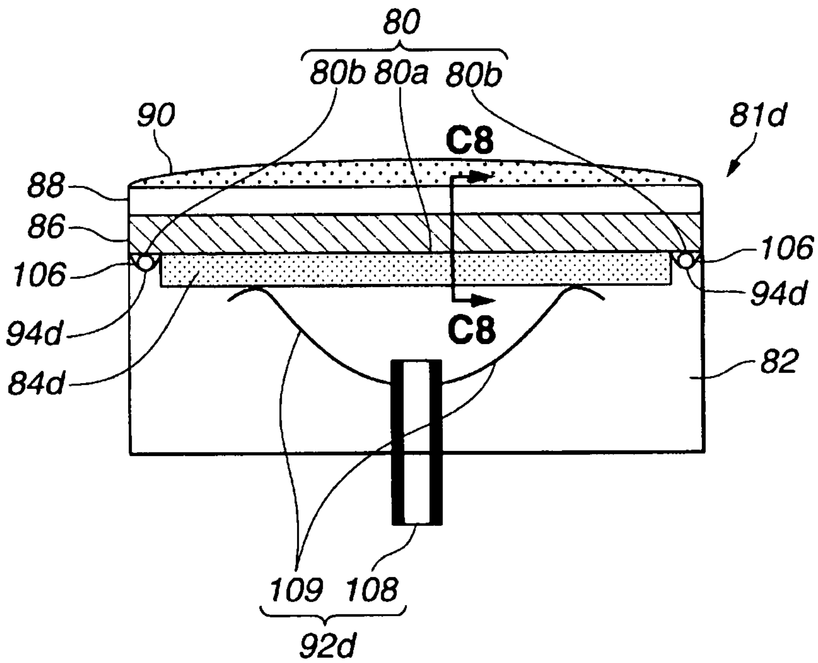

80
80b 80a 80b
90
81d
C8
88
86
106
106
94d
94d
84d
C8
82
109 108
92d

FIG.22

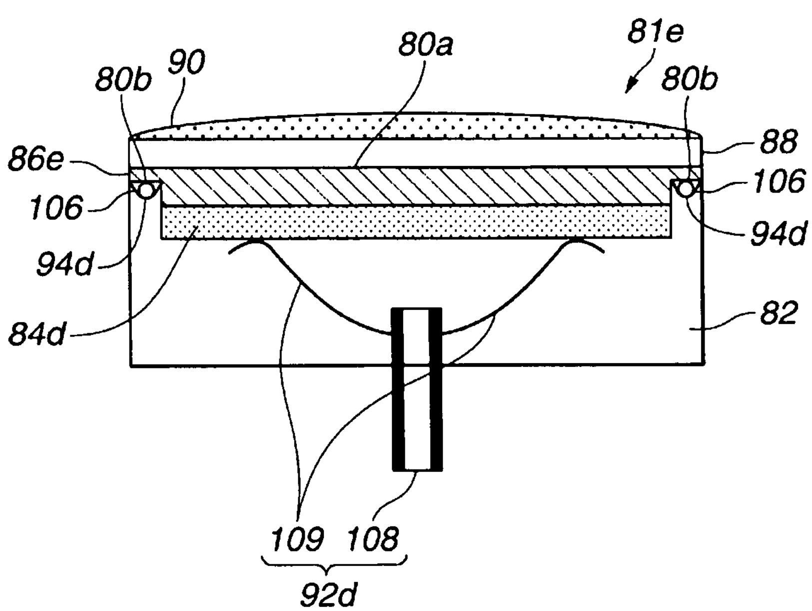

81e
80a
80b 90
80b
86e
88
106
106
94d
94d
84d
82
109 108
92d

FIG.23A

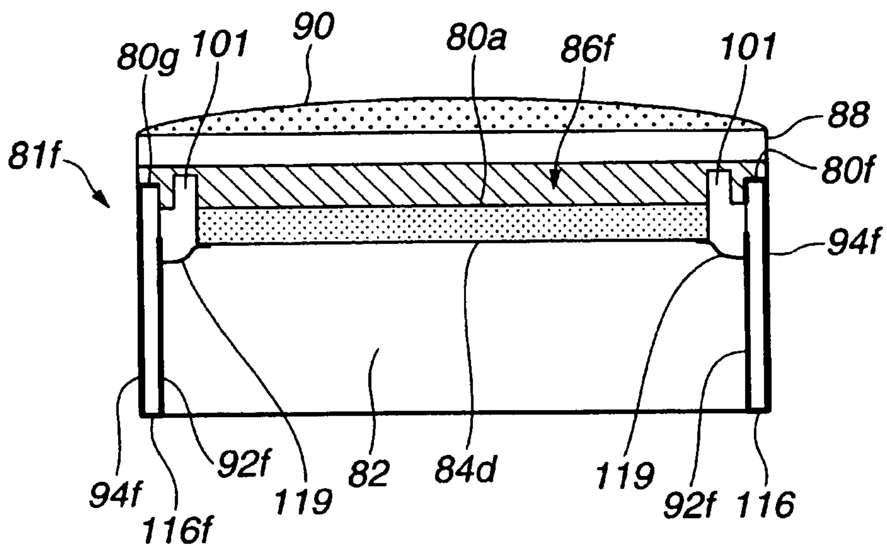


FIG.23B

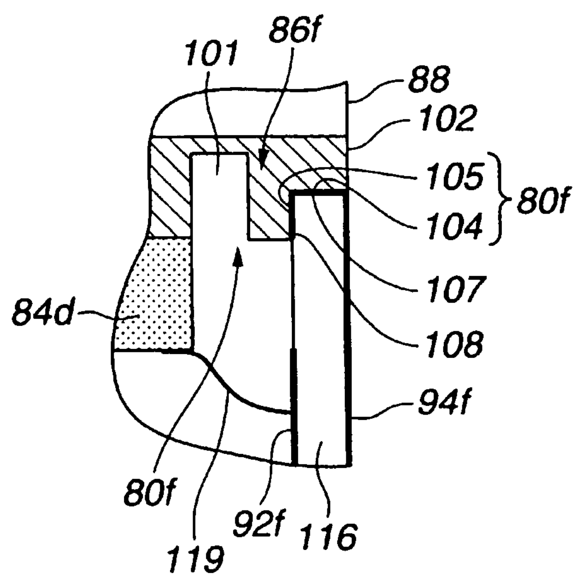


FIG.24A

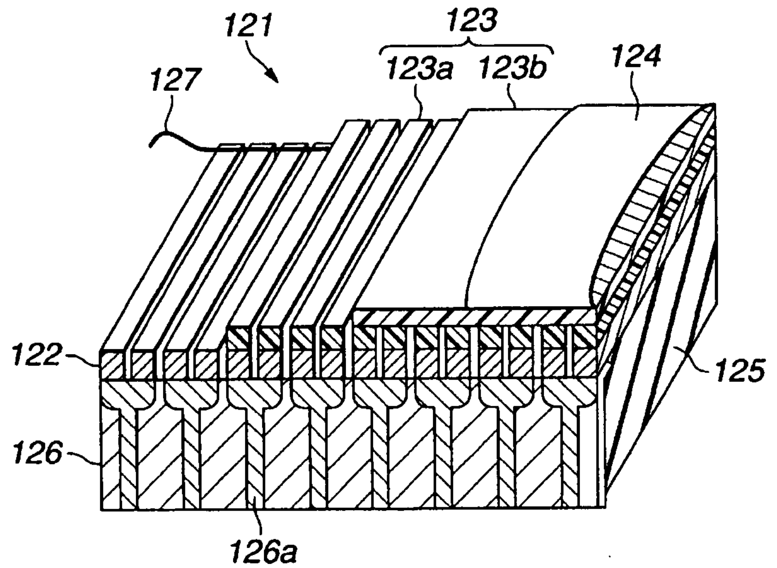


FIG.24B

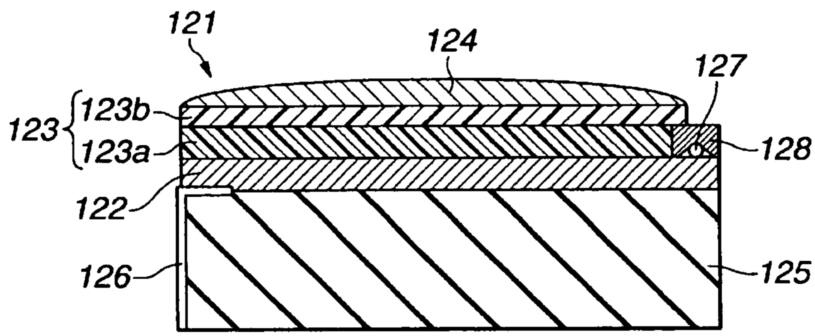


FIG.24C

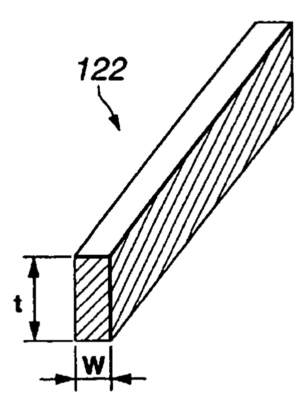


FIG.25A

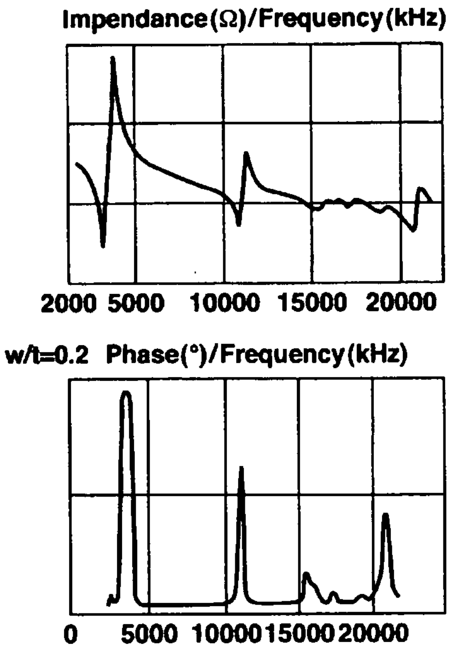


FIG.25B

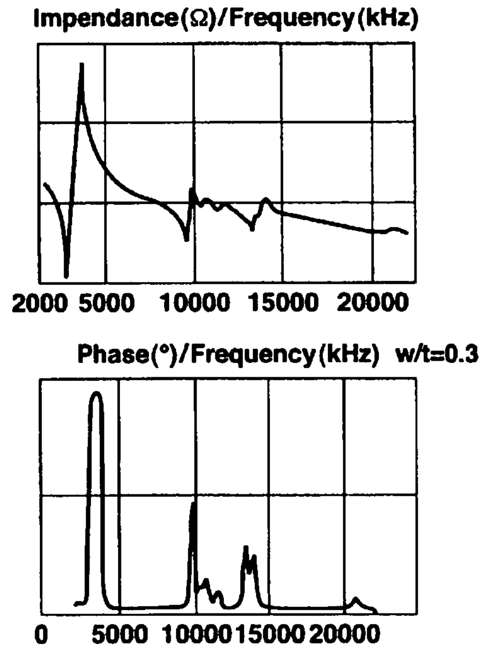


FIG.25C

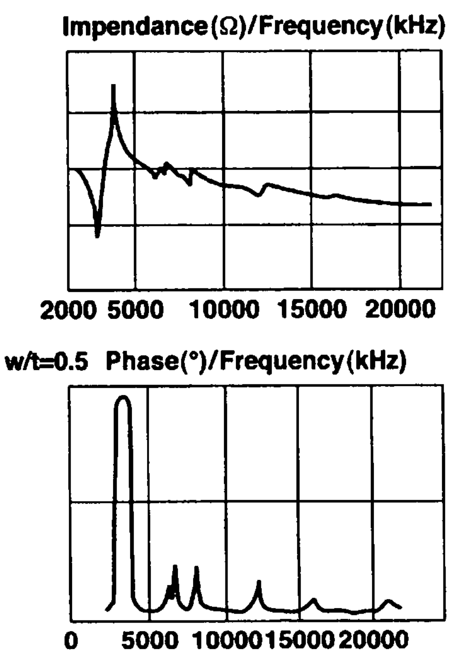


FIG.25D

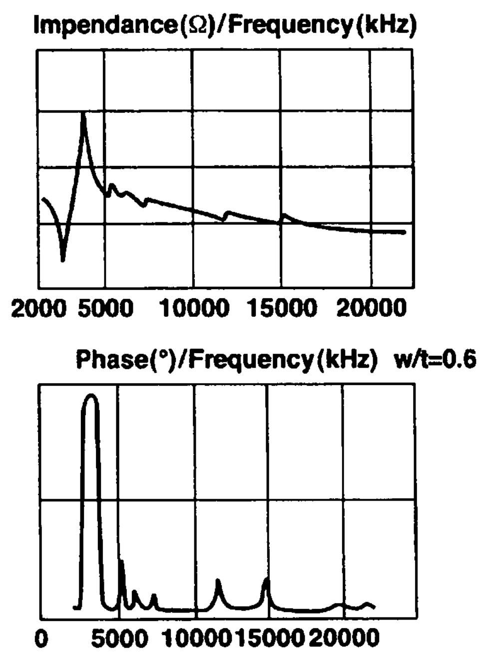


FIG.26A

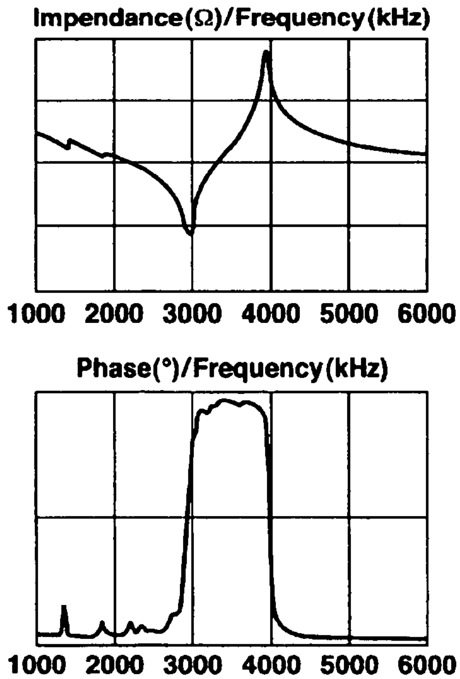


FIG.26B

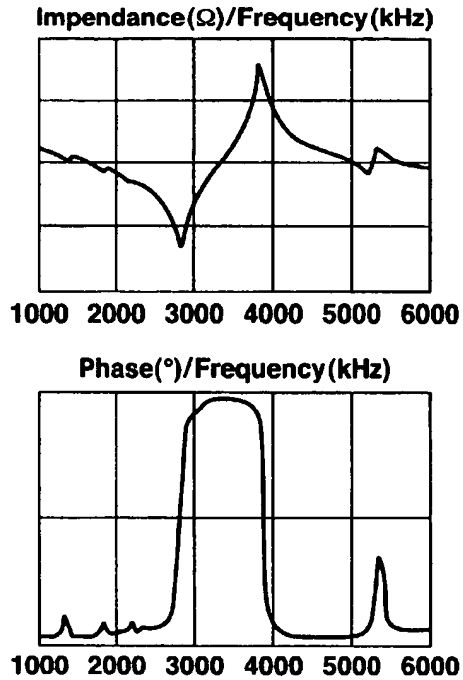


FIG.26C

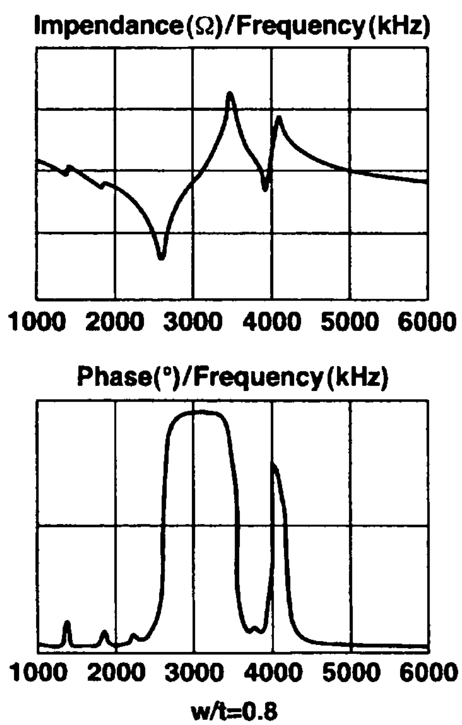


FIG.27A

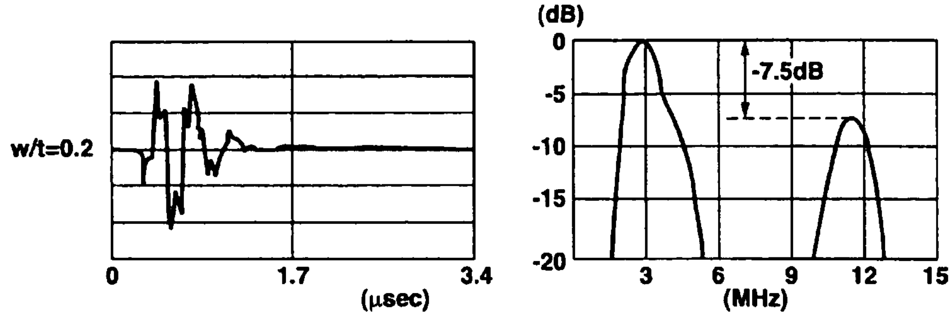


FIG.27B

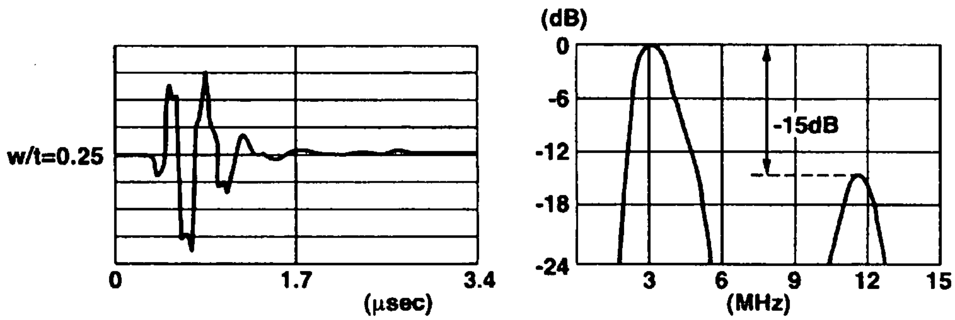


FIG.27C

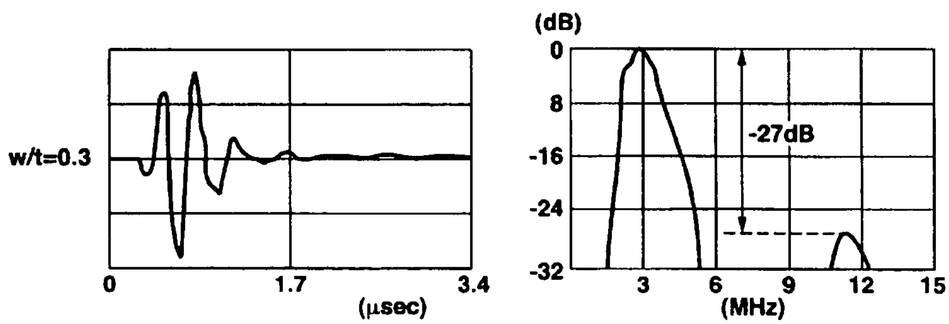


FIG.27D

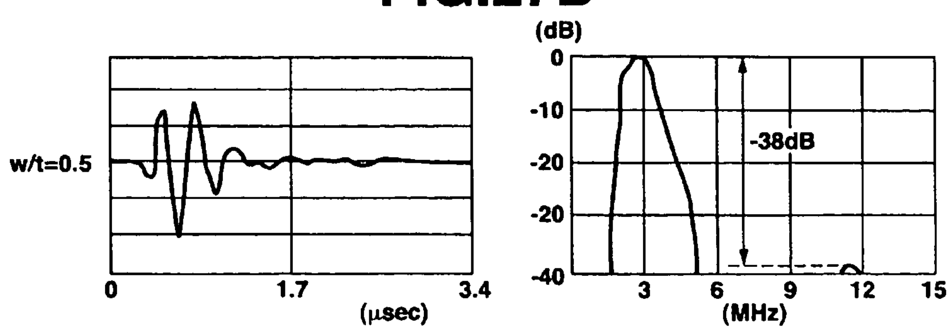


FIG.28

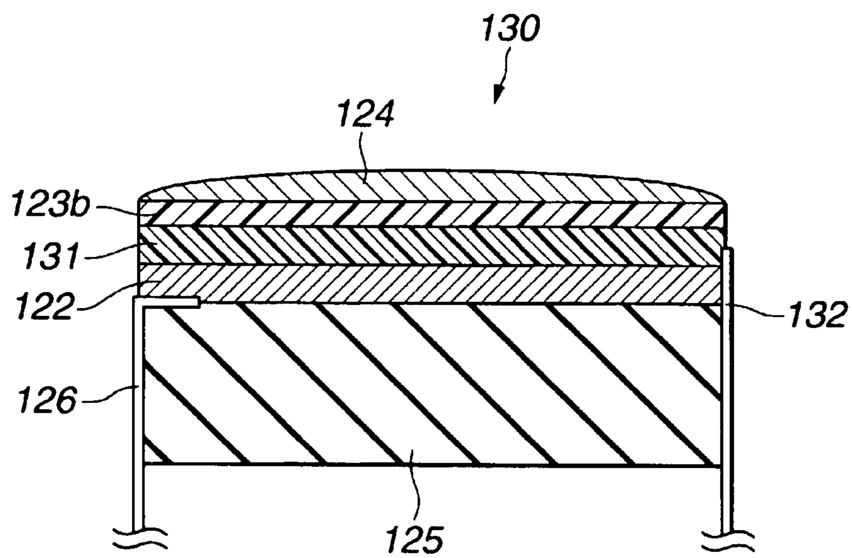
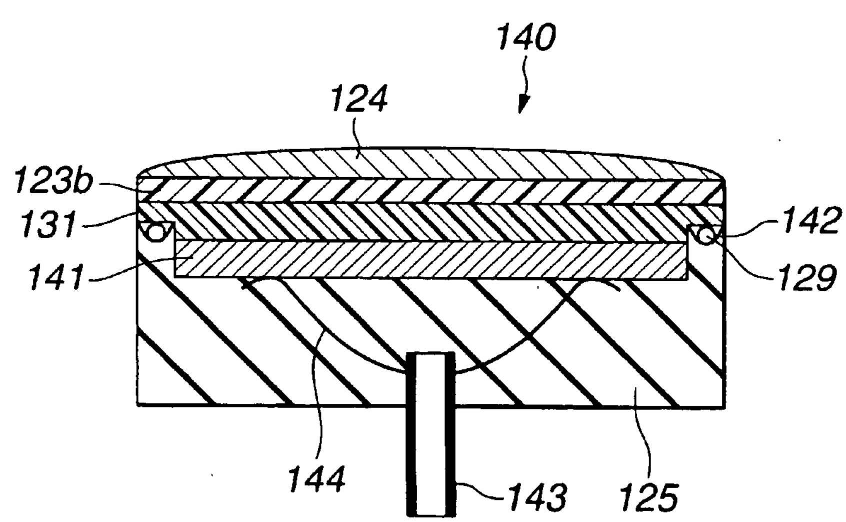

130
124
123b
131
122
132
126
125

FIG.29


140
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123b
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FIG.30A

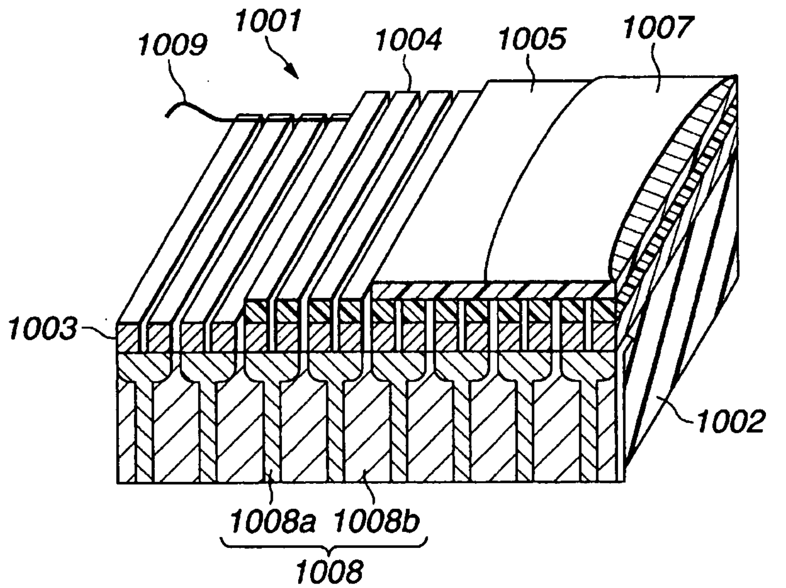


FIG.30B

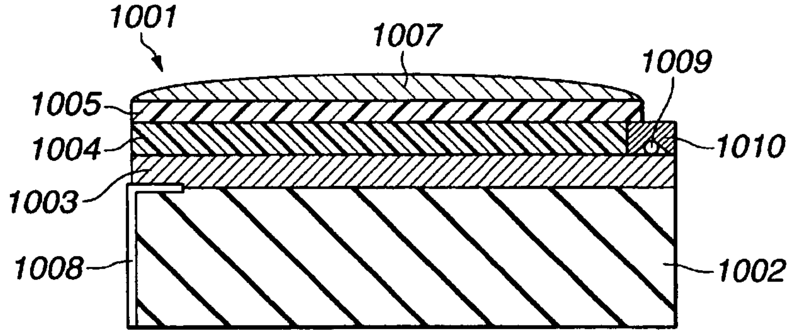
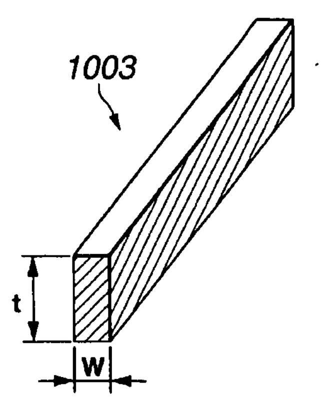


FIG.31



ULTRASOUND TRANSDUCER ARRAY

This application claims benefit of Japanese Application Nos. 2001-22202, filed in Japan on Jan. 30, 2001; 2001-43785, filed in Japan on Feb. 20, 2001; and 2000-363641, filed in Japan on Nov. 29, 2000, the contents of which are incorporated by this reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to an ultrasound transducer array, used in ultrasound diagnosis for medical use or for non-destructive inspection.

2. Description of the Related Art

In recent years, ultrasound diagnostic equipment using ultrasound transducers has come into widespread use in medical diagnostics and other fields. In addition to mechanical scanning-type ultrasound transducers which rotate a single ultrasound transducer or similar to mechanically scan with ultrasound, electronic scanning-type ultrasound transducers have also been adopted.

Such electronic scanning-type ultrasound transducers are formed using ultrasound transducer arrays, in which ultrasound transducers are formed in an array shape.

Conventional electronic scanning-type ultrasound transducers (ultrasound transducer arrays) provide signal electrodes and ground electrodes on each side of a piezoelectric element, and one or more grooves, extending to a depth partway through a provided matching layer, to divide the element and form a plurality of elements. Here, the ground electrodes must be connected to a common line.

As a method of connecting the ground electrodes to a common line, the matching layer adjacent to the piezoelectric element may be made of a conductive resin, and grooves are provided being extended to a depth midway through the matching layer, as in Japanese Unexamined Patent Application Publication No.61-253999.

However, if the thickness of the remaining matching layer is small, the strength of the matching layer is relatively weakened, so that when a force is applied, cracks may appear in the matching layer, or conduction faults may occur.

On the other hand, if the thickness of the remaining matching layer is large (if the groove cut into the matching layer is shallow), cross talk may occur, and the image quality may worsen.

SUMMARY OF THE INVENTION

An object of this invention is to provide a progressive ultrasound transducer array, which prevents the occurrence of cross talk and in which a common connection of the ground electrodes of piezoelectric elements can be reliably secured.

In this invention, an ultrasound transducer array, in which are arranged a plurality of piezoelectric elements, which can be electrically operated independently, comprises one or a plurality of matching layers, provided on the acoustic radiating surface side of the above piezoelectric elements; a conductive material layer, provided on the side of the above matching layers joined with the above piezoelectric elements, in the direction along the array direction, part of which is in contact with and electrically connected to the above piezoelectric elements along the above array direction, and part of which is not in contact with the above piezoelectric elements along the above array direction; a

plurality of grooves, which mechanically and electrically insulate at least part of the above piezoelectric elements and the above matching layer for each element which can be electrically operated independently; and, conductive material which fills at least a part of the portions of the above grooves which are formed where the above piezoelectric elements and the above conductive material layer are not in contact.

The above and other objects, features and advantages of the invention will become more clearly understood from the following description, referring to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 through FIG. 4 relate to a first aspect of the invention;

FIG. 1 is a perspective view showing the entirety of an ultrasound transducer array;

FIG. 2 is a cross-sectional view showing the cross-sectional structure in the array direction;

FIG. 3 is a cross-sectional view showing the internal structure in the elevation direction;

FIG. 4 is an explanatory diagram showing the internal structure before filling with backing material in FIG. 3;

FIG. 5 is an explanatory diagram showing the internal structure of the ultrasound transducer array of a second aspect of the invention;

FIG. 6 is an explanatory diagram showing the internal structure of an ultrasound transducer array of a modification of the second aspect;

FIG. 7 is an explanatory diagram showing the internal structure of an ultrasound transducer array of a third aspect of the invention;

FIG. 8 is an explanatory diagram showing the internal structure of an ultrasound transducer array of a modification of the third aspect;

FIG. 9 is an explanatory diagram showing the internal structure of an ultrasound transducer array of a fourth aspect of the invention;

FIG. 10 is a cross-sectional view showing the structure of an ultrasound transducer array of a fifth aspect of the invention;

FIG. 11 through FIG. 13 relate to a sixth aspect of the invention;

FIG. 11 is a perspective view showing the appearance of an ultrasound transducer array;

FIG. 12 is a cross-sectional view showing the structure of the element array;

FIG. 13 is a cross-sectional view showing the structure in the elevation direction;

FIG. 14 through FIG. 17 relate to a seventh aspect of the invention;

FIG. 14 is a side view of an ultrasound transducer array;

FIG. 15 is a cross-sectional view along line C1—C1 in FIG. 14;

FIG. 16 is a cross sectional view of the layered member of an ultrasound transducer array manufactured using a first manufacturing method;

FIG. 17 is a perspective view of the parent layered member of an ultrasound transducer array manufactured using a second manufacturing method;

FIG. 18 is a cross-sectional view of an ultrasound transducer array of an eighth aspect of the invention;

FIG. 19 is a cross-sectional view of an ultrasound transducer array of a ninth aspect of the invention;

FIG. 20 is a side view of the layered member of an ultrasound transducer array of a tenth aspect of the invention;

FIG. 21 is a cross-sectional view, showing a section parallel to the front plane, of an ultrasound transducer array of an eleventh aspect of the invention;

FIG. 22 is a cross-sectional view, showing a section parallel to the front plane, of an ultrasound transducer array of a twelfth aspect of the invention;

FIG. 23 relates to a thirteenth aspect of the invention;

FIG. 23A is a cross-sectional view, showing a section parallel to the front plane, of an ultrasound transducer array;

FIG. 23B is an explanatory diagram showing in enlargement the wiring area and groove of the ultrasound transducer array of FIG. 23A;

FIG. 24 through FIG. 27 relate to a fourteenth aspect of the invention;

FIG. 24A is a summary perspective view showing the configuration of an ultrasound transducer array;

FIG. 24B is a cross-sectional view of FIG. 24A;

FIG. 24C is a perspective view showing only a piezoelectric element of FIG. 24A;

FIG. 25 are first graphs showing the impedance curve with the ratio w/t of the thickness t to the width w of a piezoelectric element varied;

FIG. 25A is a graph showing the impedance curve when w/t =0.2;

FIG. 25B is a graph showing the impedance curve when w/t =0.3;

FIG. 25C is a graph showing the impedance curve when w/t =0.5;

FIG. 25D is a graph showing the impedance curve when w/t =0.6;

FIG. 26 are second graphs showing the impedance curve with the ratio w/t of the thickness t to the width w of a piezoelectric element varied;

FIG. 26A is a graph showing the impedance curve near the fundamental resonance point when w/t=0.5;

FIG. 26B is a graph showing the impedance curve near the fundamental resonance point when w/t=0.6;

FIG. 26C is a graph showing the impedance curve near the fundamental resonance point when w/t=0.8;

FIG. 27 are third graphs showing the echo waveform and spectrum of an ultrasound transducer array with the ratio w/t of the thickness t to the width w of a piezoelectric element varied;

FIG. 27A is a graph showing the echo waveform and spectrum of an ultrasound transducer array for which w/t=0.2;

FIG. 27B is a graph showing the echo waveform and spectrum of an ultrasound transducer array for which w/t=0.25;

FIG. 27C is a graph showing the echo waveform and spectrum of an ultrasound transducer array for which w/t=0.3;

FIG. 27D is a graph showing the echo waveform and spectrum of an ultrasound transducer array for which w/t=0.5;

FIG. 28 is a summary cross-sectional view showing an ultrasound transducer array of a fifteenth aspect of the invention;

FIG. 29 is a summary cross-sectional view showing an ultrasound transducer array of a sixteenth aspect of the invention;

FIG. 30 are configuration diagrams showing a conventional ultrasound transducer array;

FIG. 30A is a summary perspective view showing the configuration of an ultrasound transducer array;

FIG. 30B is a side cross-sectional view of FIG. 30A; and,

FIG. 31 is a perspective view showing only a piezoelectric element of FIG. 30A.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Below, first through sixth aspects of this invention are explained, based on FIG. 1 through FIG. 13.

FIG. 1 through FIG. 4 show a first aspect of the invention. The ultrasound transducer array 1 shown in FIG. 1 has a backing material framework 3 positioned on the inside of the acoustic lens 2; a cable wiring board 4 is provided vertically on the inside of this backing material framework 3, and the vicinity of the cable wiring board 4 is filled with backing material 5.

Signal wiring lands 8, 8, . . . , 8, connected by a signal wires 7 to numerous piezoelectric elements 6, 6, . . . , 6 formed in an array shape as shown in FIG. 2, are provided in the length direction on both sides of the cable wiring board 4.

On both surfaces of the cable wiring board 4, near the top, GND wiring lands 9 are formed in a strip shape in the length direction, and are electrically connected, for example, by a connection wire 10 at both end positions by a conducting film 11 provided on the inner face of the backing material framework 3 and by solder 12 or similar.

As shown in FIG. 2, FIG. 3 and FIG. 4, signal electrodes 13*a* and ground electrodes 13*b* are formed on the upper and lower surfaces of each piezoelectric element 6 by evaporation deposition of gold, silver or some other metal, or by some other means; on the lower side (the acoustic radiation side), at which transmission and reception of ultrasound waves is performed, a first matching layer 14 and second matching layer 15 for matching, and an acoustic lens 2 to concentrate the emitted ultrasound waves, are formed in layers.

In this aspect, the first matching layer 14 is formed from a conductive resin (for example, an epoxy resin with carbon or a carbon composite material added) or similar. That is, the first matching layer 14 is conducted to a line common with each electrode 13 serving as the ground electrode on the lower side of each piezoelectric element 6, provided on the side of the first matching layer 14.

The numerous piezoelectric elements formed in an array shape (as an array-shape transducer) 6, 6, . . . , 6 have, for example, a width in the elevation direction (width direction) of w, as shown in FIG. 4. A belt-shaped piezoelectric element board is cut to form divided grooves 16 at a prescribed pitch in the element array direction, and long in the element array direction perpendicular to the width direction. At this time, the dicing machine on both cuts the piezoelectric element board, adhered to the first matching layer 14, on which full-coverage electrodes on both faces are provided by evaporation deposition.

In this case, the depth of the divided grooves 16 is greater than the thickness of the piezoelectric elements 6, and the grooves are formed so as to penetrate partway in the thickness direction of the first matching layer 14 connected

to the ground electrodes **13*b*** on the lower faces of the piezoelectric elements **6**. More specifically, if as in FIG. **2** the thickness of the first matching layer **14** is T, then divided grooves **16** are formed at a thickness t (thickness t is measured from the lower face of the piezoelectric elements **6**) equal to approximately 60 to 100% of the thickness T of the first matching layer **14**.

In this way, divided grooves **16** are formed to a depth sufficient to reach the first matching layer **14**, and to extend to approximately ⅔ or more of the thickness T of this layer **14**; hence the occurrence of cross talk between neighboring piezoelectric elements **6, 6**, . . . , **6** can be adequately suppressed by the dividing groove **16** between them.

By increasing the depth of the divided grooves **16**, the strength of the first matching layer **14** is relatively decreased (compared with the case in which the depth of the divided grooves **16** is small); but in this aspect, the divided grooves **16** are filled with a conductive adhesive **17** as a filler material (reinforcing material), to prevent a relative decrease in strength of the first matching layer **14**.

In this aspect, as this conductive adhesive **17**, the same conductive member as the member used to form the first matching layer **14** is impregnated and reinforced. Even if cracks appear in the first matching layer **14**, the occurrence of conduction faults can be reliably prevented by this conductive adhesive **17**.

This conductive adhesive **17** fills the portion of the divided grooves **16** in the first matching layer **14** other than the portion in contact with the piezoelectric elements **6**, as shown in FIG. **4**. The ground electrode **13*b*** of each piezoelectric element **6** is electrically connected with the first matching layer **14**, and as shown in FIG. **2**, the first matching layer **14** is electrically connected, by a conducting material (solder), with the conductive film **11** provided on the inner face of the backing material framework **3** near both ends in the array direction.

The backing material framework **3** is formed from, for example, glass-epoxy resin, with copper foil applied to the inner surface to form a conductive film **11**. The conductive film **11** is electrically connected at the upper edge to the GND wiring land **9** by a connecting wire **10**.

Each signal electrode **13*a*** on the upper-face side of each piezoelectric element **6** is electrically connected (by solder or similar) using a signal wire **7** to a signal wiring lands **8** formed in a short strip shape opposite the upper side of each signal electrode **13*a*** on the cable wiring board **4**, provided vertically such that the lower edge is not in contact with the upper face of each piezoelectric element **6**.

In this case, as shown in FIG. **2** and FIG. **4**, signal wiring lands **8** are formed, in alternation on both faces of the cable wiring board **4**, along the length direction at the same intervals as the array of piezoelectric elements **6**. That is, the array pitch on one face is double the array pitch for the piezoelectric elements **6**, and on each face, each signal electrode **13*a*** is connected to a signal wiring land **8** by a signal wire **7** at every other piezoelectric element **6**. In this way, signal wiring lands **8** are provided on each face, and by using a signal wire **7** to connect each signal electrode **13*a*** to a signal wiring land **8** at every other piezoelectric element **6**, signal electrodes can easily be connected to signal wiring lands **8** even when the array-shape piezoelectric elements **6** are formed with a small pitch.

After connecting each signal electrode **13*a*** to a signal wiring land **8** by a signal wire **7**, the vicinity of the piezoelectric elements **6** is covered by backing material **5** which absorbs or attenuates ultrasound, as shown in FIG. **3**.

Each of the signal wiring lands **8** and the GND wiring land **9** of the cable wiring board **4** are connected, by solder or other means, to one end of an ultrasound cable (not shown). The connector at the other end of the ultrasound cable is connected to ultrasound system.

As shown in FIG. **3**, the ultrasound transducer array **1** is mounted such that the portion of the acoustic lens **2** is exposed in an opening provided in a case **19**.

An ultrasound transducer array **1** configured in this way may be manufactured as follows.

An unhardened resin in liquid form which forms a second matching layer **15**, is poured into a frame member, not shown, and hardened, and the surface is machined to form the second matching layer **15** of prescribed thickness; on top of this the first matching layer **14** is similarly formed, and on top of this, the piezoelectric element board, provided with electrodes on both faces, is bonded. After formation of the second matching layer **15**, the frame member is removed.

The piezoelectric element board (.and first matching layer **14**) is divided at a prescribed pitch in the length direction using a dicing machine, such that the elements of the piezoelectric element board are completely separated, and divided grooves **16** are formed extending to a depth T which is approximately 60 to 100% of the thickness T of the first matching layer **14** beneath, to form separated array-shape piezoelectric elements **6, 6**, . . . , **6**.

Next, each dividing groove **16**, except for portions neighboring each piezoelectric element **6**, is filled with a conductive material, for example the same material as the conductive adhesive **17** used to form the first matching layer **14**, and this material is hardened to reinforce the first matching layer **14**.

Next, the cable wiring board **4**, having signal wiring lands **8** and GND wiring lands **9** on its both faces, is positioned using a jig upward the signal electrodes **13*a*** on the upper faces of the piezoelectric elements **6**, at for example the center of the effective width w in the elevation direction. Each of the signal electrodes **13*a*** on the upper face of the piezoelectric elements **6, 6**, . . . , **6** is connected to respective signal wiring lands **8** with signal wires **7**.

A rectangular-shape backing material framework **3**, with the top and bottom sides open, is mounted so as to surround the array-shape piezoelectric elements **6, 6**, . . . , **6** and cable wiring board **4**. Copper foil or other conductive film **11** is formed on the inner walls of this backing material framework **3**, and as shown in FIG. **2**, the bottom-side opening is fixed in place and connected for electrical connection with the first matching layer **14** by means of conductive adhesive. This backing material framework **3** is smaller in size than the inner dimensions of the above frame member.

Thereafter, unhardened backing material **5** is poured up to a prescribed height from the top-side aperture of the backing material framework **3**, and hardened. Then, the jig which had held the cable wiring board in place is removed, and the conductive film **11** of the backing material framework **3** is electrically connected to the GND wiring lands **9** of the cable wiring board using connecting wire **10**. An assembly fabricated in this way is housed in an acoustic lens **2** (not shown) formed in advance using a frame member, and joined such that the second matching layer **15** on the bottom is in contact with the top surface of the acoustic lens **2**.

An ultrasound cable, not shown, is connected to the cable wiring board **4**, and the connection portion is covered. The ultrasound transducer array **1** manufactured in this manner is mounted in the case **19** such that the bottom side of the acoustic lens **2** is exposed, as shown in FIG. **3**.

The operation of an ultrasound transducer array 1 manufactured in this manner is next explained.

The connector at the other end of the ultrasound cable is connected to ultrasound system, the power to the ultrasound system is turned on, and on applying the bottom face of the acoustic lens 2 to the site for inspection of the patient or similar, transmission pulses which perform electric scanning are applied to this ultrasound transducer array 1.

Transmission pulses are applied in order across the signal electrodes 13*a* and ground electrodes 13*b* for each piezoelectric element in the element array direction of the ultrasound transducer array 1, and as a result of application of these transmission pulses, the electro-acoustic transduction function of the piezoelectric elements 6 causes ultrasound excitation, so that ultrasound is emitted toward the bottom face (acoustic radiation face) and the top face. On the top-face side, the ultrasound is attenuated by the backing material 5. On the other hand, the ultrasound emitted from the bottom-face side passes through the first matching layer 14 and second matching layer 15, is focused by the acoustic lens 2, and is sent toward the site for inspection in contact with this acoustic lens 2; at this time, linear scanning is performed in the element array direction.

Reflected ultrasound, reflected by the portion of the inspection site at which the acoustic impedance changes, is received by the same piezoelectric elements 6, converted into electrical signals, subjected to signal processing by the signal processing system within the ultrasound system, and converted into image signals, and an ultrasound cross-sectional image is displayed on a monitor display screen for the case of linear scanning.

When a transmission pulse is applied across the signal electrode 13*a* and ground electrode 13*b* of a piezoelectric element 6, the transmission pulse is applied over a route as follows: signal wiring land 8 of cable wiring board 4 → signal wire 7 → signal electrode 13*a* of piezoelectric element 6 → ground electrode 13*b* → first matching layer (conductive adhesive 17 in dividing groove 16) → conductive film 11 on inner face of backing material framework 3 → connecting wire 10 → ground wiring land 9 of cable wiring board 4.

By means of this ultrasound transducer array 1, by forming deep divided grooves 16 extending to, for example, approximately ⅔ the thickness T of the first matching layer 14, cross talk between neighboring piezoelectric elements 6 in particular can be kept small. Hence cross-sectional images with high resolution in the element array direction can be obtained.

By forming deep divided grooves 16, the strength is reduced compared with the case of shallow grooves; but by filling the divided grooves 16 with a reinforcing conductive adhesive 17, this reduction in strength can be prevented.

When deep divided grooves 16 are formed, even if cracks appear in the first matching layer 14 formed from conductive material, the strength is reinforced as a result of filling the divided grooves 16 with the conductive adhesive 17, and in addition conductive properties are more reliably secured, so that the connection of the ground electrodes 13*b* to a common line can be maintained adequately.

The advantageous results of this aspect are as follows.

By forming deep divided grooves 16, extending to for example approximately 60 to 100% of the thickness T of the first matching layer 14, cross talk can be reduced sufficiently. And, by filling the divided grooves 16 with a conductive adhesive 17, a reduction in strength can be prevented. Also, a common connection of the ground electrodes 13*b* of the piezoelectric elements 6 can be reliably secured.

Next, the structure of an ultrasound transducer array of a second aspect of this invention is explained, referring to FIG. 5.

In this ultrasound transducer array 21, the first matching layer 14 made from conductive material in the ultrasound transducer array shown in FIG. 4 is replaced by a first matching layer 14' not having conductivity; groove portions 22, 22 are formed in this first matching layer 14' along the element array direction in two places where both ends of piezoelectric elements 6 make contact in the elevation direction, and conductive layers 23 are provided in each of these groove portions 22.

Because the conductor which forms the conductive layer 23 is fabricated by mixing a resin and metal powder or similar, it tends to swell on contact with water or other substances. Hence in this aspect, the conductive layer 23 is made 60 to 100% of the thickness of the first matching layer, and at least the second matching layer is reserved, in order to ensure the necessary durability.

In this aspect, when forming the divided grooves 16, the divided grooves 16 are formed more shallow than the thickness of the conductive layer 23, so that formation of the divided grooves 16 does not cause the conductive layer 23 to be separated.

Polishing or other machining is performed in order that the upper face of the first matching layer 14' and the upper face of the conductive layer 23 are in a single plane, and by bonding the piezoelectric element board with electrodes provided on both faces onto the first matching layer 14 and onto the conductive layer 23 formed in the groove portions 22, and using a dicing machine to form the divided grooves 16 similarly to the first aspect, a piezoelectric element array 6, 6, . . . , 6 is formed in which signal electrodes 13*a* and ground electrodes 13*b* are formed on the upper and lower faces respectively.

Here, the upper surface of the first matching layer 14' makes contact with the central portion of the ground electrodes 13*b* on the bottom face of each piezoelectric element 6, and the ground electrodes 13*b* on both ends in the elevation direction make contact with the conductive layer 23.

In this aspect, the portion of the divided grooves 16 which, for example, is not in contact with the piezoelectric elements 6, but which is formed in the conductive layer 23, is filled with a conductive adhesive 24 as a filler material.

As the conductive layer 23 and conductive adhesive 24, an epoxy resin with additive like carbon or a carbon composite material or similar may be adopted, for example, to impart electrical conductivity, as the case in forming the first matching layer 14 explained in the first aspect.

Further, a thermosetting resin may be adopted as the conductive layer 23 and conductive adhesive 24. In this case, the same thermosetting resin material may be adopted in both the conductive layer 23 and conductive adhesive 24. These thermosetting resins include resins which harden at room temperature.

The configuration is otherwise similar to that of the first aspect.

As one effect of this aspect, the central portion of each piezoelectric element 6 makes contact with the first matching layer 14', and both ends make contact only with the conductive layer 23, so that there are fewer constraints on the conductive material properties of the material of the first matching layer 14' compared with the first matching layer 14; hence matching is possible at more appropriate values, and more inexpensive material can be used in manufacture.

In this aspect, part of the ultrasound transmitted from the acoustic radiation surface side of the piezoelectric elements 6 which is formed by the first matching layer 14' is mainly used in formation of ultrasound images.

Other effects are similar to those of the first aspect.

The advantageous results of this aspect are as follows.

Compared with the constraint of conductive properties imposed on the first matching layer 14, there are fewer material constraints, so that matching can be performed at more appropriate values, and more inexpensive materials can be used in manufacturing. Otherwise, the advantageous results are substantially the same as for the first aspect.

As a variant of the second aspect, a structure such as that shown in FIG. 6 may be adopted. In the ultrasound transducer array 21' shown in FIG. 6, the width of the groove portion 22 in FIG. 5 is effectively broadened (made larger) to extend to the edge of the first matching layer 14'. In other words, the central portion in the elevation direction of the first matching layer 14' is reserved, and both ends are cut away to form cut-out grooves 22', 22'; each cut-out groove 22' is filled with a conductive material to form the conductive layer 23.

Except near the portions in contact with the piezoelectric elements 6, each of the cut-out grooves 22' of the divided grooves 16 is filled with conductive adhesive 24. Otherwise the configuration is similar to that of FIG. 5, and the action and advantageous results are also similar.

In this aspect (including the variant), two conductive layers 23 are provided; however, either may be provided as the sole such layer instead.

Next, the structure of the ultrasound transducer array of a third aspect of this invention is explained, referring to FIG. 7.

The ultrasound transducer array 31 of this aspect has a structure in which, after formation of the divided grooves 16 in the ultrasound transducer array 21 of FIG. 5, conductive wires 32, having common connection and reinforcement functions, are fixed with conductive adhesive 33 on the upper face of the portion of the conductive layer 23 not in contact with the piezoelectric elements 6, along the element array direction. The conductive wire 32 is formed of metal, for example silver.

The part of the divided grooves 16 near the lower side of the conductive wire 32 is filled with the conductive adhesive 33.

The effect and advantageous results of this aspect are substantially the same as in the case of FIG. 5; but by adopting the conductive wires 32, both the effect of common connection of the ground electrodes 13*b*, and the effect of reinforcement, can be enhanced.

Also, upon sterilizing the ultrasound transducer array 31 of this aspect in an autoclave, the resin part of the conductive layer 23 absorbs moisture and swells, and the electrical conductivity declines; but because the conductive wires 32 are metal wires, they are not affected by moisture and there is no decline in conductivity, so that durability with respect to sterilization can be improved.

As a variant of this aspect, a structure such as that in FIG. 8 may be adopted. The ultrasound transducer array 31' shown in FIG. 8 has a structure in which, in the ultrasound transducer array 21' shown in FIG. 6, after forming the divided grooves 16 a flat wire 32' with rectangular cross-section for making a common connection is fixed with conductive adhesive 33 to the upper face of the portion of the conductive layer 23 not in contact with the piezoelectric elements 6, along the element array direction.

Of the divided grooves 16, the part near the lower part of this flat wire 32' is filled with conductive adhesive 33.

In this case also, the effect and advantageous results are similar to those of the above case.

In this aspect, including the variant, two wires 32 or flat wires 32' are provided; but a single wire only may be provided instead.

Next, the structure of the ultrasound transducer array 41 of a fourth aspect of this invention is explained, referring to FIG. 9.

This ultrasound transducer array 41 has a structure in which, in the ultrasound transducer array 1 of FIG. 4, after forming the divided grooves 16, conductive tape 42 for common connection is fixed with conductive adhesive 47 to the upper face of the portion of the first matching layer 14 not in contact with each piezoelectric element 6, along the element array direction. This conductive tape 42 is, for example, silver tape, on one face of which is provided an adhesive portion employing conductive adhesive 47.

Of the divided grooves 16, the portions near the bottom of this conductive tape 42 are filled with the conductive adhesive 47, to ensure more reliable conduction, and to provide a reinforcement function.

The effect and advantageous results of this aspect are substantially the same as in the cases of the aspects shown in FIG. 7 and FIG. 8.

Further, by employing conductive tape 42 as the conductive member for a common connection, mounting is simplified, and a larger contact area can be secured, so that a common connection of the ground electrodes can be made reliably, and manufacture of the ultrasound transducer array 41 becomes easier.

In this aspect, two conductive tape members 42 are provided, but a single tape member may be provided instead.

Next, a fifth aspect is explained, referring to FIG. 10. This figure shows a cross-section, along a dividing groove, of the structure of an ultrasound transducer array 51.

In this ultrasound transducer array 51, a dicing machine is used to form the divided grooves 16, similarly for example to the case of the ultrasound transducer array of the first aspect; but the divided grooves 16 are not formed extending to both ends of the first matching layer 14, but only in a portion which is extends slightly beyond both ends of the piezoelectric elements 6 (in the elevation direction).

That is, as shown in FIG. 10, divided grooves 16 are formed to separate the piezoelectric elements 6, and in addition the grooves are formed sufficiently deeply in the underlying first matching layer 14, in the portion opposed to the piezoelectric elements 6, to adequately suppress cross talk.

However, divided grooves 16 are not formed near both edges of the first matching layer 14, apart from the two edges, in the elevation direction, of the piezoelectric elements 6, and so the strength of the first matching layer 14 is increased compared with the case in which divided grooves 16 are formed in these portions as well; moreover, the occurrence of cracks during machining to form the divided grooves 16 can also be prevented.

In this aspect, divided grooves 16 are not formed in the portion (at both ends) of the first matching layer 14 apart from both ends in the elevation direction of the piezoelectric elements 6, and so this portion is not reinforced with filler material. Otherwise, the configuration is similar to that of the first aspect.

This aspect has substantially the same effect and advantageous results as the first aspect, even if the portion of the

divided grooves **16** which is formed is not reinforced with conductive adhesive **17**.

In FIG. **10**, divided grooves **16** are formed in the vicinity adjacent to the piezoelectric elements **6**, and divided grooves **16** are not formed at the two ends, thereby increasing the strength of the first matching layer **14**; however, this aspect also includes a method in which the groove depth is reduced at both ends, to prevent reductions in strength.

This aspect has been explained as a variant of the first aspect with changes to the formed portions of the divided grooves **16**; however, the changes can also be applied to the other aspects. That is, in the other aspects also, the divided grooves **16** may likewise be formed only in portions which are slightly longer than the piezoelectric elements **6**.

Next, a sixth aspect of this invention is explained, referring to FIG. **11** through FIG. **13**. FIG. **11** shows the outer appearance of a curved linear-type ultrasound transducer array; FIG. **12** shows the cross-sectional structure in the element array direction; and FIG. **13** shows the cross-sectional structure in the elevation direction.

In this ultrasound transducer array, the backing material framework **63** is positioned inside the semicircular acoustic lens **62**, the cable wiring board **64** is provided vertically inside this backing material framework **63**, and the vicinity is filled with backing material **65**.

On the cable wiring board **64** are provided signal wiring lands **68**, **68**, . . . , **68** almost radially in the length direction, being connected by signal wires **67** to a plurality of piezoelectric elements **66**, **66**, . . . , **66** formed in an array along, for example, a circular arc.

Near the upper portion of the cable wiring board **64**, a GND wiring land **69** is formed in a strip shape in the length direction, and extends to ground wiring lands provided on both sides of the signal wiring lands **68**, **68**, . . . , **68**. The ground electrodes **71***b* on the bottom side of the piezoelectric elements **66**, **66**, . . . , **66** are electrically connected, by means of solder or similar, to a conductive layer **72** using connecting wires **70**.

As shown in FIG. **12** and FIG. **13**, signal electrodes **71***a* and ground electrodes **71***b* are formed, by evaporation of metal or similar means, on the upper and lower faces of each piezoelectric element **66**. On the bottom face, which performs transmission and reception of ultrasound, a first matching layer **74** and second matching layer **75** for matching, and an acoustic lens **62** for concentration of the emitted ultrasound, are formed in layers.

As shown in FIG. **13**, grooves are formed on the upper face of the first matching layer **74** opposite both ends in the elevation direction of the piezoelectric element **66**, and conductive layers **72** are formed in the grooves.

In this aspect, the first matching layer **14** is formed from, for example, epoxy resin.

The numerous piezoelectric elements **66**, **66**, . . . , **66** formed in an array are formed by providing full-coverage electrodes by evaporation deposition or similar on both faces of a belt-shape piezoelectric element board formed along a cylinder surface, bonding to this a first matching layer **74**, and, by using a dicing machine to form divided grooves **76** so as to separate elements, forming an array of elements separated in the array direction along the cylinder surface.

Except for the portion adjacent to the piezoelectric elements **66**, the portion of each dividing groove **76** in which is formed a conductive layer **72** is filled with a conductive filler material **77**, for common connection to the ground electrodes **71***b* and for reinforcement.

Except for the fact that ultrasound is transmitted and received radially, this aspect has substantially the same effect and advantageous results as the first aspect.

In each of the above-described aspects, it is preferable that the divided grooves be deep rather than shallow, in consideration of the effect of cross talk. Also, in the above-described aspects a matching layer is formed from a first matching layer and a second matching layer; however, a single matching layer may be used or, three or more matching layers may be used.

Aspects which are configured by partial combination of the above-described aspects or similar, also, fall within the scope of this invention.

The above has mainly explained the structure of ultrasound transducers. The following explanation places emphasis on selection of materials.

Japanese Unexamined Patent Application Publication No.9-139998 discloses an ultrasound transducer array having a back load member, piezoelectric elements, matching layer comprising carbon as a conductive material, and acoustic lens, with these layered in order similarly to the ultrasound transducer array **1001** shown in FIG. **30**A and FIG. **30**B. The matching layer is joined, with electrical conductivity ensured, to electrodes formed on the upper faces of the piezoelectric elements. The matching layer also serves as a grounding electrode.

Japanese Patent Publication No.1-61062 discloses an ultrasound transducer array having a back load member, piezoelectric elements, and matching layer comprising conductive resin as a conductive material, with these layered in order. The conductive resin is formed by intermixing metal powder as a filler into a resin material as a matrix. Similarly to Japanese Unexamined Patent Application Publication No.9-139998, the matching layer is used as a ground electrode.

However, in the ultrasound transducer array of Japanese Unexamined Patent Application Publication No.9-139998 using carbon in the matching layer, whereas the matching layer has electrical conductivity and good cutting properties, while when the thickness typically used for the matching layer is (¼)λ, mechanical strength is reduced, and cracks and chips appear during machining into thin sheets.

In cases where uncombined carbon is used to form the matching layer, when the ultrasound transducer array is used with the human body, the acoustic impedance of the acoustic impedance-matching layer deviates from the optimal value. As a result, ultrasound is not propagated efficiently, sensitivity declines, and image definition deteriorates.

In the ultrasound transducer array of Japanese Patent Publication No.1-61062, using conductive resin for the matching layer, by appropriately choosing the filler material and the resin material as the matrix, electrical conductivity can be obtained; but in addition to aging, during such processes as disinfecting and sterilization, the disinfectant and sterilizing fluids may penetrate into the resin and cause degradation or swelling of the resin, or oxidation or other changes to the metal filler, worsening electrical conductivity and increasing the resistance value. As a result the S/N ratio decreases, and conduction faults and image quality deterioration occur. Also, the conductive resin is a material with large ultrasound attenuation factor, so that transmission and reception sensitivity and image quality are reduced.

Hence there is a need for an ultrasound transducer array comprising a matching layer which is conductive, not prone to cracking or chipping during machining, which is easy to machine, and has an optimal acoustic impedance.

Below, seventh to thirteenth aspects of this invention are explained, referring to FIG. 14 through FIG. 23.

FIG. 14 through FIG. 17 show the seventh aspect of this invention. FIG. 14 is a side view of an ultrasound transducer array; FIG. 15 is a cross-sectional view of a layered member, cut along line C1—C1 in FIG. 14; FIG. 16 is a side view of the layered member of an ultrasound transducer array manufactured by a first manufacturing method; and FIG. 17 is a perspective view of the principal components of the parent layered member of an ultrasound transducer array manufactured by a second manufacturing method.

The ultrasound transducer array 81 of this aspect has a back load member 82. The back load member 82 is formed from a flexible urethane resin, with alumina used as a filler. The urethane resin has a Shore hardness of approximately A90.

In FIG. 14, the front surface of the back load member 82, which is one of the four surfaces, faces the plane of the paper. On the upper surface of the back load member 82 are layered, in the order of a piezoelectric element 84, first matching layer 86, and second matching layer 88. The piezoelectric element 84 is formed from a piezoelectric ceramic manufactured by ordinary sintering processes or similar.

Electrodes are formed on the lower surface (the surface opposed to the upper surface of the back load member 82) and the upper surface of the piezoelectric element 84. The first matching layer 86 comprises a carbon composite material containing carbon, and is conductive.

A conductive layer (not shown) provided at the portion of this first matching layer 86 which is in contact with both ends in the elevation direction of the piezoelectric element 84 is formed by intermixing carbon powder with a thermosetting resin matrix. This carbon powder may be the same as the powder of the carbon composite material used to form the first matching layer 86. The thermosetting resin may be a material which hardens at room temperature.

The thickness of the first matching layer 86 is 200 μm, and when using 5 MHz ultrasound, the ultrasound is propagated efficiently. The second matching layer 88 is formed from an epoxy resin, and is of thickness 100 μm. The piezoelectric element 84, first matching layer 86 and second matching layer 88 form a layered member.

In FIG. 16, the front surface (the surface facing the plane of the paper in FIG. 14) of the layered member is facing the plane of the paper, and the top and bottom are reversed from their positions in FIG. 14. The lower surface of the layered member is the lower surface of the piezoelectric element 84. On the layered member are formed a plurality of array grooves 85, extending along the lower surface of the layered member. These array grooves 85 extend substantially parallel to the front surface of the layered member and in substantially straight lines, and are positioned at prescribed intervals.

As shown in FIG. 16, the array grooves 85 are formed between the lower surface of the piezoelectric element 84 (the surface in contact with the back load member 82) and a line 83 passing through the second matching layer 88. Through formation of the array grooves 85, the piezoelectric element 84 and first matching layer 86 are each divided into a plurality of portions. Focusing on the first matching layer 86, the array grooves 85 extend along the surface of the first matching layer 86, and the depth of each dividing groove 85 is, at all portions of the dividing groove 85, equal to the thickness of the first matching layer 86, such that the first matching layer 86 is divided. An acoustic lens 90 is provided on top of the second matching layer 88 (FIG. 14). The acoustic lens 90 is formed from silicone resin. The upper surface of the acoustic lens 90 is formed in a convex shape.

In the back load member 82, a substantially flat flexible printed board 92 extends in the vertical direction along a side surface adjacent to the front surface. The top end of the flexible printed board 92 is enclosed between the upper surface of the back load member 82 and the lower surface of the piezoelectric element 84. The other hand is connected to a pulser and observation equipment, not shown, similarly to the conventional ultrasound transducer array 1001 shown in FIG. 30A and FIG. 30B.

A plurality of lead wires are positioned on the flexible printed board 92. These lead wires are connected, via solder, to electrodes on the lower surface of corresponding portions of the divided piezoelectric elements 84. The flexible printed board 92 is used as signal lines to transmit driving signals and received signals.

In the ultrasound transducer array 81, a substantially flat flexible printed board 94 having a full-coverage electrode is bonded with conductive adhesive to the side surface opposite the side surface on which the flexible printed board 92 is provided. The piezoelectric element 84 and first matching layer 86 are electrically connected, and by bonding the flexible printed board 94 to the first matching layer 86, the first matching layer 86 forms a common electrode for each of the portions of the divided piezoelectric element 84.

A polyimide insulator is positioned on the portion of the flexible printed board 94 adjacent to the piezoelectric element 84. By this means, the electrode on the lower surface of the piezoelectric element 84 is insulated from the flexible printed board 94. The flexible printed board 94 is connected to ground, not shown, and used as a ground line.

As described above, the electrode on the upper surface of the piezoelectric element 84 is connected to the first matching layer 86 and to ground via a ground line. The action of the ultrasound transducer array 81 is similar to that of the ultrasound transducer array 1001 of FIG. 30A and FIG. 30B, and an explanation is here omitted.

Next, the material forming the first matching layer 86 is explained. As described above, the first matching layer 86 is formed from a carbon composite material. This carbon composite material contains carbon and carbides. These carbides contain silicon carbide (SiC) and boron carbide (B_4C). The above carbon composite material contains fine ceramic powder of these carbides, and fine ceramic powder of borides. The carbon composite material is formed into sintered members.

The strength of the first matching layer 86 comprising this carbon composite material is higher compared with a layer comprising carbon alone. This is thought to arise by the following reasons.

The carbon composite material is formed primarily from granular carbon and from fine ceramic particles existing between the carbon grains. The fine ceramic particles are embedded like wedges between adjacent carbon grains. By this means, adjacent carbon grains are not easily separated by fine ceramic particles, so that the growth of microcracks is believed to be suppressed. In particular, when the shape of the fine ceramic particles is polygonal having protrusions and depressions (a combination of polygons) rather than spherical, there is a strong action binding carbon grains in place, and strength can be expected to be improved.

In this way, there is little occurrence of cracking and chipping during machining of the carbon composite material, so that machining is relatively easy. Particularly

when used with high-frequency ultrasound at 10 MHz or more, the matching layer must be machined to a thickness of 100 μm or less, but this machining to a thin shape can also be performed easily.

The carbon composite material is formed by intermixing carbon with silicon carbide (SiC) having an average particle diameter of 0.5 μm and boron carbide (B_4C) having an average particle diameter of 5 μm. The mass fractions of the silicon carbide (SiC) and of the boron carbide (B_4C) are respectively 6 wt % (mass percentage) and 9 wt %. In addition to these, 4 wt % zirconium boride is also intermixed with the carbon. The acoustic impedance is approximately 8.5×10^6 kg/m^{2}s (8.5 MRayl).

The carbon composite material contains fine ceramic particles of density higher than carbon, so that compared with uncombined carbon, the density is higher. Consequently the acoustic impedance of the carbon composite material is larger than that of uncombined carbon.

If the proportion of carbides intermixed in the carbon composite material (that is, the mass fraction) is changed, or the average grain diameter is varied, the acoustic impedance changes. Typically, acoustic impedances between approximately 7.5×10^6 kg/m^{2}s (7.5 MRayl) and approximately 10×10^6 kg/m^{2}s (10 MRayl) can be obtained. By this means, a matching layer which has optimal acoustic impedance can be prepared for the efficient propagation of ultrasound.

In the case of a resin formed with a filler intermixed in the resin material, if the intermixed filler is modified, the acoustic impedance also changes. However, such a resin has a large ultrasound attenuation factor, so that if a matching layer using such a resin is employed, the ultrasound is not propagated efficiently. In particular, a conductive resin such as that disclosed in Japanese Patent Publication No.1-61062 contains a filler with a unique shape in order to secure conductivity, and for this reason has a still larger attenuation factor, so that this defect is more prominent. Compared with such a resin, a carbon composite material has a comparatively small ultrasound attenuation factor, and so ultrasound propagates comparatively efficiently. In this way, by using a matching layer consisting of a carbon composite material, a stronger driving signal can be guided to the object, and a stronger received signal can be made incident on the piezoelectric element. Hence the sensitivity of the ultrasound transducer array **81** can be improved.

In this aspect, the carbon composite material is formed by mixing silicon carbide (SiC), boron carbide (B_4C) and zirconium boride into carbon; but a similar advantageous result to that of the carbon composite material of this aspect is obtained from a carbon composite material in which, in place of mixing the above compounds with carbon, aluminum carbide (Al_4C_3) and other carbides, and tungsten boride (WB) and similar, are mixed with carbon. Also, an advantageous result similar to that of the carbon composite material of this aspect is also obtained if at least one among silicon carbide (SiC), boron carbide (B_4C), zirconium boride, aluminum carbide (Al_4C_3), and tungsten boride (WB), is intermixed.

In an ultrasound transducer array **81** with such a configuration, by varying the ratio of silicon carbide (sic) and boron carbide (B_4C), the acoustic impedance of the carbon composite material can be modified, and so an ultrasound transducer array **81** can be provided comprising a matching layer having an optimal acoustic impedance.

Further, because the carbon composite material does not swell due to moisture or water as resins do, this material can be durable even for transducers subjected to harsh washing or requiring sterilization for use within the body.

Of course various modifications and alterations of the configurations of this aspect are possible. When using 5 MHz ultrasound, the thickness of the first matching layer **86** is 200 μm; but this invention is not limited to this thickness. For example, in order to use 10 MHz ultrasound, the thickness may be made 100 μm. Also, in order to use ultrasound with an arbitrary frequency, it is of course possible that the thickness can correspond to the frequency.

In this aspect, by providing an insulator on the surface of the flexible printed board **94** facing the piezoelectric elements **84**, the flexible printed board **94** is insulated from the electrodes on the lower surface of the piezoelectric elements **84**; however, this invention is not limited to this configuration. For example, insulation may be effected by forming the electrodes on the lower surface of the piezoelectric elements **84** such that the electrodes on the lower surface of the piezoelectric elements **84** are not exposed to the outside from a crevice between a side surface of the piezoelectric elements **84** and a side surface of the first matching layer **86**. The portion of the electrodes on the lower surface of the piezoelectric elements **84** which are exposed to the outside may be insulated by sealing with resin.

In this aspect, the flexible printed board **92** is connected to the electrodes of the piezoelectric elements **84** via solder; but this invention is not thereby limited. For example, connection may be made by an anisotropic conductive film (ACF). In this case, depolarization of piezoelectric elements **84** arising from contact of the piezoelectric elements **84** with heated solder can be prevented.

The piezoelectric elements **84** may be curved in a convex shape in a direction intersecting the direction in which the array grooves **85** extend. Such an ultrasound transducer array **81** is called a convex-array probe.

Next, method of manufactures of the ultrasound transducer array **81** of this aspect is explained. Two methods of manufacture of the ultrasound transducer array **81** are conceivable.

Initially, a first manufacturing method is explained.

First Process:

Carbon composite material containing prescribed carbides is prepared, and this carbon composite material is ground to shape a substantially flat first matching layer **86**.

As explained above, the thickness of the first matching layer **86** is 200 μm. In order to shape carbon composite material to a thickness of 200 μm, a two-sided lapping machine may be used, or wax or a water-soluble adhesive may be used to apply the carbon composite material to a base, and grinding and polishing performed to machine the carbon composite material.

Second Process (process of formation of the second matching layer):

A framework is mounted so as to cover the side faces of the first matching layer **86**, forming a container, and tape or similar is used to mask one surface of the first matching layer **86**.

A water-soluble resin or resist may be used for masking. The bottom face of this container is the first matching layer **86**; the side faces constitutes the framework. The masked surface is the surface facing outside the container.

Next, epoxy resin is poured into the container, and the resin is hardened to form the second matching layer **88**. The amount of resin poured is adjusted such that the thickness of the second matching layer **88** is 100 μm. Then the framework and masking are removed.

Third Process (process to form a layered member):

A piezoelectric element **84** which is substantially flat and with electrodes formed on the upper and lower surfaces is prepared. The upper surface of the piezoelectric element **84** is bonded with adhesive to the surface of the first matching layer **86** from which the masking was removed, to form a layered member comprising the piezoelectric element **84**, first matching layer **86**, and second matching layer **88**.

Fourth Process (process to connect signal lines):

The flexible printed board **92**, serving as signal lines, is connected via solder to the electrode on the bottom surface of the piezoelectric element **84** (the reverse side surface of the surface in contact with the first matching layer **86**).

Fifth Process (process to form array grooves):

As shown in FIG. **16**, the blade **93** of a precision cutting machine is moved from one side surface adjacent to the front surface of the layered member to the other side surface, along a line **83** in the direction of the arrow in the figure. As explained above, the line **83** penetrates the second matching layer **88**. By repeating this movement, the array grooves **85** shown in FIG. **15** are formed.

Sixth Process:

Using a framework similar to that of the second process, the back load member **82** is formed using urethane resin on the bottom surface of the piezoelectric elements **84**.

Next, conductive adhesive is used to bond the flexible printed board **94**, serving as a ground line, to the side surface of the first matching layer **86**. Then, silicone resin is used to form an acoustic lens **90** on the upper surface (the reverse side surface of the surface in contact with the first matching layer **86**) of the second matching layer **88**.

As described in detail above, in the first method of manufacture of the ultrasound transducer array **81**, there is little occurrence of cracking or chipping during machining, and by using easily-machined carbon composite material as the first matching layer **86**, manufacturing can be performed easily.

In the first process of this first manufacturing method, in order to enable the use of 5 MHz ultrasound, the carbon composite material is ground to form a first matching layer **86** of thickness 200 μm. However, in order to use ultrasound at still higher frequencies, the carbon composite material may be machined to a thinner shape. In this case, because the carbon composite material is such that cracking and chipping do not readily occur during machining, machining can be performed more easily than the machining to a thin shape of uncombined carbon such as is used in the matching layer of Japanese Unexamined Patent Application Publication No.9-139998.

It is preferable that the content of fine ceramic powder including carbides in the carbon composite material used as the matching layer of this invention be from 10 to 50 wt %. If 50 wt % or more is intermixed, electrical conductivity worsens, and because of the high hardness of the carbides such as SiC and B_4C which are intermixed to suppress microcracks, the lifetime of grinding tools used in machining is shortened, and as a result it becomes difficult to reduce the cost of the probe. If the content is 10 wt % or less, the effect in suppressing microcracks is reduced. It is preferable that the carbon composite material be sintered and bake-hardened.

In order to manufacture a convex-array probe, the layered member may be curved in a convex shape. The second matching layer **88** is formed from epoxy resin, and is flexible. By using this to deform the vicinity of the array grooves **85** in the second matching layer **88** after forming the layered member of FIG. **15**, a convex-array probe can be manufactured.

Next, a second method of manufacture of the ultrasound transducer array **81** is explained. The above-described first manufacturing method and the second manufacturing method are essentially the same.

Differences between the first manufacturing method and the second manufacturing method are the provision of a process to cut the layered member between the third process (process to form the layered member) and the fourth process (process for signal line connection) of the first manufacturing method.

The layered member (parent layered member) is formed according to the first through third processes (layered member formation processes) of the first manufacturing method, and in the next process, the blade **93** of a precision cutting machine is used to cut the unmachined layered member (parent layered member) along the lines **96**.

As in FIG. **17**, lines **96** in a lattice shape show the portions of the parent layered member to be cut. The surface of the parent layered member is larger than four times the surface of the layered member formed according to the first manufacturing method.

The parent layered member has a piezoelectric element **84'** which is effectively the same as the piezoelectric element, first matching layer and second matching layer formed in the first manufacturing method; a first matching layer **86'**; and a second matching layer **88'**. There exist four windows in the lines **96** in a lattice shape. When the parent layered member is cut along the lines **96**, four layered members (child layered members) **97, 98, 99, 100** corresponding to the four windows of the lattice are obtained. The remaining portions of the parent layered member are discarded.

Then, by performing the fourth process (process to connect signal lines) and subsequent processes of the above first manufacturing method, the ultrasound transducer array **81** shown in FIG. **14** is obtained.

In the above-described first manufacturing method, the side surfaces of the layered member formed in the third process (process to form the layered member) and previous processes may be smeared with epoxy resin leaked from the framework of the second process (process to form the second matching layer) or with the adhesive used in the third process (process to form the layered member).

However, in the second manufacturing method, the portions which had been in contact with the side surfaces of the parent layered member are discarded after cutting, so that the side surfaces of the child layered members are not smeared. Hence in the sixth process, the flexible printed board **94** can be bonded to the side surface of a child layered member free of smearing, and so there is no intervening adhesive or other insulator. Thus reliability is improved when securing electrical conductivity at the side surface of the carbon composite material. Also, the contact strength and bonding durability can be improved.

The time required to form four child layered members through this manufacturing method is approximately ¼ the time required to form four layered members through the above-described first manufacturing method. By means of this manufacturing method, ultrasound transducer arrays **81** can be manufactured rapidly and at low cost.

In this aspect, the layered member is cut along the lines **96** in a lattice shape having four windows; but this invention

is not thus limited. The number of windows may be two or three, or may be five or more. Also, the window shape is not limited to a quadrilateral, but may for example be a hexagon. Also, the method for cutting the layered member is not limited to a lattice.

FIG. 18 shows a cross-sectional view of the ultrasound transducer array of an eighth aspect of this invention. The configuration of the ultrasound transducer array **81**a of this aspect is basically the same as that of the ultrasound transducer array **81** of the seventh aspect, and the configuration as seen from the front of the ultrasound transducer array **81** is the same as in the seventh aspect; hence an explanation is given referring to FIG. **14** as a side view of the ultrasound transducer array **81**a of this aspect, and to FIG. **16** as a side view of the layered member of this aspect.

Differences between the configuration of this aspect and the configuration of the seventh aspect; hence in FIG. **14** and FIG. **16**, the first matching layer is indicated by the symbol **86**a instead of the symbol **86**, and the second matching layer is indicated by the symbol **88**a instead of the symbol **88**.

FIG. **18** is a cross-sectional view of the layered member, along the line C1—C1 in FIG. **14**. In the layered member of the seventh aspect shown in FIG. **15**, the array grooves **85** are formed from the lower surface of the piezoelectric elements **84** to the second matching layer **88**, but in the layered member shown in FIG. **18**, the array grooves **85**a are only formed up to the first matching layer **86**a.

Referring to FIG. **16** and FIG. **18**, the array grooves **85**a are formed between the lower surface of the piezoelectric elements **84** and the line **34** penetrating the first matching layer **86**a. Concerning the first matching layer **86**a, the depth of the array grooves **85**a is, throughout the entirety of the array grooves **85**a, less than the thickness of the first matching layer **86**a.

In the eighth aspect of an ultrasound transducer array **81**a configured as described in detail above, the first matching layer **86**a is not divided by the array grooves **85**a, so that by connecting wires to a part of the conductive first matching layer **86**a, an electrical connection is made entirely to the divided portions of the first matching layer **86**a. Hence the flexible printed board **94** used as a ground line need not be bonded to all divided portions of the first matching layer **86**a. Bonding to at least one portion of the first matching layer **86**a is sufficient, and so a highly reliable ultrasound transducer array **81** with simple configuration can be provided.

The ultrasound transducer array **81**a of this aspect can, in essence, be manufactured by either the first or the second method for manufacturing the ultrasound transducer array **81** of the above-described seventh aspect. However, in the fifth process (process to form array grooves), the blade **93** of the precision cutting machine is moved along the lines **34** rather than along the lines **83**.

FIG. **19** shows a cross-sectional view of the ultrasound transducer array of a ninth aspect of this invention. The configuration of the ultrasound transducer array **81**b of this aspect is essentially the same as the configuration of the ultrasound transducer array **81** of the seventh aspect.

The configuration seen from the front of the ultrasound transducer array **81**b of this aspect is the same as that of the seventh aspect, and so FIG. **14** is again referenced as a side view of the ultrasound transducer array **81**b of this aspect.

Differences in the configuration of this aspect and the configuration of the seventh aspect are the configurations of the first matching layer and the second matching layer; hence in FIG. **14**, the first matching layer is indicated by the symbol **86**b instead of the symbol **86**, and the second matching layer is indicated by the symbol **88**b instead of the symbol **88**. FIG. **19** is a cross-sectional view of the layered member along the line C1—C1 in FIG. **14**.

The array grooves **85** of the seventh aspect shown in FIG. **15** and FIG. **16** are formed up to the line **83** penetrating the second matching layer **88**. However, the array grooves **85**a shown in FIG. **16** and FIG. **18** are formed up to the line **34** passing through the first matching layer **86**a. Different from the layered member of the seventh aspect, in the layered member of the ninth aspect there are regularly intermixed main dicing grooves **52**, which are grooves of depth similar to the array grooves **85**, and sub-dicing grooves **54**, which are grooves of depth similar to the array grooves **85**a, as shown in FIG. **19**. If the main dicing grooves **52** are abbreviated "deep" and the sub-dicing grooves **54** are abbreviated "shallow", then these grooves are arranged in the order "shallow", "shallow", "deep", "shallow", "shallow", "deep", "shallow", "shallow", with two sub-dicing grooves **54** isolated by main dicing grooves **52**.

As a result, the portions of the piezoelectric element **84** divided by the main dicing grooves **52** are further separated into three portions by the two sub-dicing grooves (for example, the portions **55**, **56**, **57**). On the other hand, in the portion **58** of the first matching layer **86**b separated by main dicing grooves **52**, sub-dicing grooves **54** are formed, but this portion **58** is not divided, and remains continuous. The portions **55**, **56**, **57** of the piezoelectric element **84** are mutually electrically connected via the portion **58** of the first matching layer **86**b. The portions **55**, **56**, **57** and the portion **58** form a single driving unit. The layered member has a plurality of such driving units.

In the seventh aspect, the flexible printed board **94** must be bonded to all portions of the divided first matching layer **86**. In an ultrasound transducer array **81**b configured as described in detail above, the flexible printed board **94** need only be bonded to one portion of each driving unit, so that reliability with respect to electrical conduction faults can be improved. Further, the portions of the piezoelectric element **84** forming driving units are further divided by the sub-dicing grooves **54**, so that the sensitivity of the ultrasound transducer array **81**b can be improved.

In this aspect, two sub-dicing grooves **54** are isolated by main dicing grooves **52**; however, the present invention is not thus limited. For example, single sub-dicing groove may be isolated by main dicing grooves; or, three or more sub-dicing grooves may be so isolated.

The piezoelectric elements **84** may be curved in a direction intersecting the direction in which the main dicing grooves **52** extend. Utilizing the fact that the second matching layer **88**b is flexible, by deforming the second matching layer **88**b near the main dicing grooves **52**, and arranging the driving units in a convex shape, a convex-array probe can be formed.

The ultrasound transducer array **81**b of this aspect can in essence be manufactured by either the first or the second method of manufacturing the ultrasound transducer array **81** of the above-described seventh aspect. However, in the fifth process (the process to form the array grooves), the blade **93** of the precision cutting machine is moved along the line **83** or the line **34** in order to form the main dicing grooves **52** or the sub-dicing grooves **54**, respectively.

FIG. **20** is a side view of the layered member of the ultrasound transducer array of a tenth aspect of this invention. The configuration of the ultrasound transducer array **81**c of this aspect is essentially the same as the configuration

of the ultrasound transducer array **81** of the seventh aspect. The configuration as seen from the front of the ultrasound transducer array **81***c* of this aspect is the same as that of the seventh aspect, and so FIG. **14** is again referenced as a side view of the ultrasound transducer array **81***c* of this aspect.

Also, the configuration of the layered member of this aspect as seen along the line C1—C1 of FIG. **14** is the same as that of the seventh aspect, and so FIG. **15** is again referenced as a cross-sectional view of the layered member of this aspect.

Differences between the configuration of this aspect and that of the seventh aspect are the configurations of the first and the second matching layers; hence in FIG. **14** and FIG. **15**, the first matching layer, second matching layer, and array grooves are indicated by the symbols **86***c*, **88***c* , **85***c* instead of the symbols **86**, **88**, **85**, respectively.

In FIG. **20**, similarly to FIG. **16**, the front surface of the layered member faces the plane of the paper, and the top and bottom are reversed relative to FIG. **14**. In the seventh aspect, the bottom surfaces of the array grooves **85** are along a line **83** which penetrates the second matching layer **88**, as shown in FIG. **16**; but in this aspect, the bottom surfaces of the array grooves **85***c* are along the line **864** in FIG. **20**. That is, the bottom surfaces of the array grooves **85***c* extend in a straight line up to point B from one side surface of the second matching layer **88***c* through the interior of the second matching layer **88***c*, similarly to the line **83**, but from point B, extend to the side surface of the first matching layer **86***c* opposite the above side surface. Consequently, concerning the first matching layer **86***c*, the depth of the array grooves **85***c* near the above side surface of the first matching layer **86***c* is less than the thickness of the first matching layer **86***c*.

In other portions, the thickness of the array grooves **85***c* is equal to the thickness of the matching layer **86***c*. The first matching layer **86***c* is continuous via the portions **862** of the first matching layer **86***c*, positioned between the bottom surface of the portion of the array grooves **85***c* at which the depth is less than the thickness of the first matching layer **86***c* and the second matching layer **88***c*. The piezoelectric element **84** is divided by the array grooves **85***c*. Each of the divided portions of the piezoelectric element **84** is electrically connected via the portions **862** of the conductive first matching layer **86***c*.

Similarly to the eighth aspect explained using FIG. **18**, in an ultrasound transducer array **81***c* configured as explained in detail above, the flexible printed board **94** used as a ground line need be bonded to only a portion of the first matching layer **86***c*, so that a highly reliable ultrasound transducer array **81***c* with simple configuration can be provided.

The ultrasound transducer array **81***c* of this aspect can in essence be manufactured by the first or the second method of manufacture of the ultrasound transducer array **81** of the above-described seventh aspect. However, in the fifth process (the process to form the array grooves), in order to form the array grooves **85***c*, the tip of the blade **93** of the precision cutting machine is for example moved along the line **864** from point A in the direction of the arrow in FIG. **20**, stopped at point B, and from point B is removed by moving in the direction perpendicular to the line **864**.

An eleventh aspect of this invention is shown in FIG. **21**. The figure is a cross-sectional view of the ultrasound transducer array **81***d*, in the plane parallel to the front surface (similar to the surface facing the plane of the paper in FIG. **14**).

The configuration of the ultrasound transducer array **81***d* of this aspect is in essence the same as the configuration of the ultrasound transducer array **81** of the seventh aspect. In this aspect, constituent members which are effectively the same as constituent members explained referring to FIG. **14** through FIG. **16** in explaining the seventh aspect are assigned the same reference symbols as those used for the corresponding members of the seventh aspect, and detailed explanations are omitted.

A difference between the configuration of this aspect and the configuration of the seventh aspect is the configuration of the piezoelectric element, signal lines, and ground lines. The lower surface **80** of the first matching layer **86** (the surface opposed to the piezoelectric element **84***d*) is larger than the upper surface of the piezoelectric element **84***d* (the surface opposed to the first matching layer **86**). The upper surface of the piezoelectric element **84***d* is an acoustic radiation surface which radiates ultrasound. The lower surface **80** of the first matching layer **86** is used as an opposed region **80**. The opposed region **80** comprises the junction region **80***a* joined to the acoustic radiation surface of the piezoelectric element **84***d*, and the regions **80***b* joined to the acoustic radiation surface. Copper wires **94***d* used as ground lines are positioned on the regions **80***b*. The regions **80***b* are used as wiring regions **80***b*. The wires **94***d* are connected to the wiring regions **80***b* using conductive resin **106**. The wiring regions **80***b* extend from the front surface of the ultrasound transducer array **81***d* to the back surface (the reverse surface of the front surface) along the side surfaces of the ultrasound transducer array **81***d*, together with the wires **94***d*, and are connected to all the portions of the first matching layer **86** divided by the array grooves **85**.

In this aspect, wires **94***d* are shown as one example of conductive members; but the conductive members need not be formed in wire shape, and may instead be formed in ribbon shape, rod shape, or foil shape.

The cross-sectional plane of the layered member along the line C8—C8 is effectively the same as the layered member cross-section shown in FIG. **15**. Below the piezoelectric element **84***d*, the substantially flat glass-epoxy resin **108** extends from the front surface of the ultrasound transducer array **81***d* to the back surface (the reverse surface of the front surface) in the direction orthogonal to the direction in which the array grooves **85** extend (the direction perpendicular to the plane of the paper in FIG. **21**). A plurality of wires are connected to both ends of the glass-epoxy resin **108**. At both ends of the glass-epoxy resin **108**, electrodes corresponding to these wires are arranged in the length direction in portions close to the piezoelectric element **84***d*.

These electrodes are connected to the electrodes on the lower surface of portions corresponding to the divided piezoelectric elements **84***d*, via wires **94***d*. The wires **94***d* are connected to the piezoelectric elements **84***d* using solder. The glass-epoxy resin **108** and wires **94***d* are used as signal lines **92***d*. A portion of the glass-epoxy resin **108** and the wires **94***d* are positioned within the back load member **82**.

In cases where high-frequency ultrasound is to be used, the first matching layer **86** is made thin. Hence if, as in the seventh aspect, a ground line is connected to a side surface of the first matching layer **86**, the area over which the first matching layer **86** is in contact with the ground line (the contact area) is small, and so it is difficult to ensure that conduction faults do not occur.

However, in an ultrasound transducer array **81***d* configured as described in detail above, by connecting a portion of the lower surface of the first matching layer **86** (the surface opposed to the piezoelectric element **84***d*) to the ground line, the contact area is not affected by the thickness of the first

matching layer **86**, and so conduction faults can be reliably prevented regardless of the frequency of use.

The configuration of the layered member of this aspect is effectively the same as the configuration of the layered member of the seventh aspect shown in FIG. **15**, but this invention is not thus limited. For example, the configuration may be effectively the same as the configuration of the eighth aspect shown in FIG. **18**, or the ninth aspect shown in FIG. **19**. Or, the configuration may be effectively the same as the configuration of the tenth aspect shown in FIG. **20**.

Next, the method of manufacture of the ultrasound transducer array **81***d* of this aspect is explained. The ultrasound transducer array **81***d* of this aspect can in essence be manufactured by the first manufacturing method used to manufacture the ultrasound transducer array **81** of the above-described seventh aspect.

First, the layered member is formed according to the first through the third process (process to form the layered member). In the third process, a piezoelectric element **84***d* having an acoustic radiation surface smaller than the lower surface of the first matching layer **86** is prepared. When the piezoelectric element **84***d* is bonded to the first matching layer **86**, the piezoelectric element is positioned with respect to the first matching layer **86** such that wiring regions **80***b* are formed.

Next, the array grooves **85** are formed according to the fifth process (process to form array grooves). Then, the wires **94***d* and signal lines **92***d* are connected, and the back load member **82** and acoustic lens **90** are formed.

In cases where high-frequency ultrasound is to be used, as described above, if ground lines are connected to the side faces of the first matching layer **86** as in the seventh aspect, the area over which the first matching layer **86** makes contact with the ground lines (the contact area) is small, and so it is difficult to connect the ground lines to the first matching layer **86**.

In this respect, in the method for manufacture of the ultrasound transducer array **81***d* of this aspect, the ground lines are connected to a comparatively large contact area, so that the connection operation is easy. Also, the ground lines can be securely connected, so that manufacturing yields are improved.

FIG. **22** shows a twelfth aspect of the invention. This figure is a cross-sectional view in a plane parallel to the front plane (similar to the plane facing the plane of the paper in FIG. **21**) of the ultrasound transducer array **81***e*.

The configuration of the ultrasound transducer array **81***e* of this aspect is in essence the same as that of the ultrasound transducer array **81***d* shown in FIG. **21**. A difference in the configuration of this aspect with that of the eleventh aspect is the configuration of the first matching layer.

In the first matching layer **86** shown in FIG. **21** above, the junction region **80***a* and wiring regions **80***b* exist in the same plane. However, in the first matching layer **86***e* of this aspect, the wiring regions **80***b* are sunken with respect to the junction region **80***a*. Even configured in this way, advantageous results similar to those of the ultrasound transducer array **81***d* of the eleventh aspect can be obtained.

Next, a method for manufacturing the ultrasound transducer array **81***e* of this aspect is explained. In essence, manufacture is possible using the second method of manufacture of the ultrasound transducer array **81** of the above-described seventh aspect.

First, the parent layered member shown in FIG. **17** is formed. Then, grooves (hereafter "wiring grooves") are formed along either the vertical lines, or the horizontal lines, of the lines **96** in a lattice shape in the lower surface (the reverse surface of the piezoelectric element **84'** that is in contact with the first matching layer **86'**) of the parent layered member, in order to form the sunken wiring regions **80***b*. The width of the wiring grooves is larger than twice the width of the wiring regions **80***b*. The wiring grooves extend in the depth direction as far as the interior of the first matching layer **86***e*.

Next, the process to cut the parent layered member of the second manufacturing method is performed. However, when cutting along the wiring grooves, cutting is performed through the center in the width direction of the wiring grooves, along the center line extending in the length direction of the wiring grooves. Then, the signal lines **92***d* and wires **94***d* are connected, and the back load member **82** and acoustic lens **90** are formed, similarly to the method for manufacturing the ultrasound transducer array **81***d* shown in FIG. **21**.

In the method of manufacture of the ultrasound transducer array **81***d* of the twelfth aspect, when the piezoelectric element **84***d* is bonded to the first matching layer **86**, the adhesive may adhere to the wiring regions **80***b*. If so, there is an increased possibility of the occurrence of conduction faults.

With respect to this, in the method of manufacture of the ultrasound transducer array **81***e* of this aspect, by forming the wiring grooves prior to the process of cutting the layered member, adhesive on the wiring regions **80***b* is removed, so that ultrasound transducer arrays **81***e* can be manufactured rapidly and at low cost, and reliability with respect to conduction faults can be improved.

In the eleventh aspect and this aspect, two wires **109**, each extending from respective surface of the glass-epoxy resin **108**, are used to improve reliability; of course a single wire extending from one surface can also be used to obtain a similar advantageous result.

FIG. **23**A and FIG. **23**B show a thirteenth aspect of this invention. FIG. **23**A is a cross-sectional view of the ultrasound transducer array **81***f* in a plane parallel to the front plane (similar to the plane facing the plane of the paper in FIG. **14**); FIG. **23**B is an enlarged view of one of the wiring regions **80***f* and one of grooves **101**.

Grooves **101** are formed between the junction region **80***a* of the first matching layer **86***f* of this aspect, and the wiring regions **80***f*, **80***g* used for wiring. The configuration of the ultrasound transducer array **81***f* of this aspect is in essence the same as the configuration of the ultrasound transducer array **81***d* shown in FIG. **21**.

A difference between the configuration of this aspect and that of the eleventh aspect is the configuration of the matching layer, signal lines and ground lines. The wiring region **80***f* is formed in the portion in contact with the side surface **102** (a side surface adjacent to the front surface). The wiring region **80***f* is defined by the upper surface **104** of the wiring region orthogonal to the side surface **102** which is continuous with the side surface **102** and extends along the side surface **102**, and the wiring region side surface **105** which is continuous with the wiring region upper surface **102** and extends parallel to the side surface **102**.

A substantially flat glass-epoxy board **116** extends along the side surface (surface adjacent to the front surface) of the ultrasound transducer array **81***f* from the back load member **82** toward the first matching layer **86***f*. One end of the glass-epoxy board **116** is inserted into the wiring region **80***f*.

On the glass-epoxy board **116**, a ground electrode is formed in the portion **107** opposed to the wiring region

upper surface 104 and in the portion 108 opposed to the wiring region side surface 105, extending along the wiring region 80f. That is, the first matching layer 86f is in contact on two surfaces with a ground electrode in the wiring region 80f. The contact area between the first matching layer 86f and the ground electrode is large, so that reliability against electrical conduction faults is high. This electrode is connected to a single wire 94f positioned on the surface of the glass-epoxy board 116 facing outside, and is used as a ground line.

The configuration of the wiring region 80g and the glass-epoxy board 116f which is connected to the wiring region 80g is effectively the same as the configuration of the wiring region 80f and the glass-epoxy board 116 respectively. A difference between the former and the latter is that an electrode is formed on the portion 108 of the glass-epoxy board 116, but no electrode is formed on the portion of the glass-epoxy board 116f corresponding to the portion 108. That is, the first matching layer 86f is in contact with a ground electrode at one surface in the wiring region 80g.

A plurality of wires 92f are positioned as signal lines on the surfaces facing inward of the glass-epoxy boards 116, 116f. These wires are connected using solder to the electrodes on the lower surfaces in portions corresponding to divided piezoelectric elements 84d via wires 119.

If, as in the conventional ultrasound transducer array 1001 shown in FIG. 30A and FIG. 30B, a ground line 1009 spans two neighboring portions among the plurality of portions of a divided first matching layer 1004, vibrations propagate between these portions via this ground line 1009, so that mechanical cross talk may occur. In this aspect, however, by forming the groove 101, vibrations are not easily transmitted to the glass-epoxy boards 116, 116f, so that mechanical cross talk can be prevented.

In this aspect, wires 92f used as signal lines are connected using solder to electrodes on the bottom surface of the piezoelectric element 84d via wires 119; but this invention is not thus limited. For example, wire bonding may also be used. When using solder, there may be variations in the amount of solder for each of the wires 119, so that differences in loads for different wires 119 may occur. If wire bonding is used, differences in loads can be reduced, and so the characteristics of the ultrasound transducer array 81f can be stabilized. Also, solder may be used to make connections via conductors other than wire.

Next, a method of manufacture of the ultrasound transducer array 81f of this aspect is explained.

The ultrasound transducer array 81f can, in essence, be manufactured by the method of manufacture of the ultrasound transducer array 81d of the eleventh aspect shown in FIG. 21.

First, similarly to the eleventh aspect, a layered member having a small piezoelectric element 84d is formed. Then, the array grooves 85, wiring regions 80f, 80g, and grooves 101 are formed. Following this, the glass-epoxy boards 116, 116f and wires 119 are mounted, and the back load member 82 and acoustic lens 90 are formed.

In this aspect, a ground electrode to which is connected a wire 94f used as a ground line is directly bonded to the first matching layer 86f using conductive adhesive; but this invention is not thus limited. For example, wire bonding may be used, similarly to the wires 92f used as signal lines. In this case, sputtering or another method is used to provide gold, aluminum, or some other metal on the portion of the first matching layer 86f to be wire-bonded. By using wire bonding, the time required for manufacture can be shortened compared with cases in which conductive adhesive is used, so that wire bonding is suited to mass production.

In this aspect, the electrode of the piezoelectric element 84d on the side of the first matching layer 86f is used as a ground electrode, but if a sufficiently high breakdown voltage is secured for the acoustic lens 90 and second matching layer 88 and similar, the patterning of the glass-epoxy boards 116, 116f may be modified, and the signal line and ground line interchanged.

In each of the aspects described above, a piezoelectric ceramic obtained by ordinary sintering is used as the piezoelectric element; but a piezoelectric single crystal may be used instead.

In each of the above-described aspects, the ultrasound transducer arrays 81 and 81a to 81e have been described in detail as having divided piezoelectric element portions arranged in a one-dimensional array. Of course, a carbon composite material containing carbides, of which material itself has small ultrasound attenuation and an optimal acoustic impedance, is easily machined and can be formed into thin shapes, can be applied to an ultrasound transducer array using a piezoelectric element not divided by array grooves or to an ultrasound transducer array in which divided piezoelectric element portions are arranged in two dimensions.

Below, the dimensions of elements in the configuration of the ultrasound transducer arrays described thus far are explained.

In Japanese Patent Publication No.62-2813, for example, an embodiment is proposed in which an ultrasound transducer array 1001 has a ratio w/t of the width w in the array direction of a single piezoelectric element 1003, shown in FIG. 31, to the thickness t in the acoustic radiation axis direction, being equal or less than 0.8, and in particular being w/t=0.66 (w=0.4 mm, t=0.6 mm).

However, if in the ultrasound transducer array of the above Japanese Patent Publication No.62-2813 the ratio w/t of the width in the array direction of a single piezoelectric element 1003 to the thickness t in the acoustic radiation axis direction of the above piezoelectric element 1003 is made much smaller than 0.8, the problem described below occurs.

If the ratio w/t of the width w to the thickness t of the above piezoelectric element 1003 is set such that w/t<0.3, vibration modes in the transverse direction are small, but higher-order vibrations in the thickness direction become large. In an ultrasound transducer array 1001 configured with at least one row of such piezoelectric elements 1003, high-harmonic vibrations will occur (see FIG. 25A, FIG. 25B).

Due to this occurrence of high harmonics, energy in the ultrasound transducer array 1001 is also distributed to high harmonic components, so that there is energy loss in the fundamental frequency component, and the sensitivity declines.

Also, because of the presence of these high harmonic components in the ultrasound transducer array 1001, disorder appears in the transmitted sound field formed by electronic focusing in order to electronically focus the ultrasound, so that artifacts occur, and the accuracy of the result of ultrasound beam synthesis upon reception is reduced. Consequently the resolution of the resulting ultrasound diagnostic image is degraded.

On the other hand, if the ratio w/t of the width w to the thickness t of the above piezoelectric elements 1003 is set to 0.6 to 0.8, the electromechanical transduction efficiency is

improved, but transverse-direction vibration modes appear. Consequently problems similar to the above-described high harmonic components arise, cross talk and increases in pulse width occur due to radial-direction vibrations, and there is degradation of the resolution of ultrasound diagnostic images resulting from imaging.

Hence the piezoelectric element **1003** must have a high electromechanical transduction efficiency and must be of a shape which suppresses the occurrence of unnecessary vibration modes.

Therefore, the provision of an ultrasound transducer array having piezoelectric elements with a high electromechanical transduction efficiency, of an optimal shape for suppressing the occurrence of unnecessary vibration modes, and enabling the enhancement of image resolution, is desired.

Below, fourteenth through sixteenth aspects of this invention are explained, referring to FIG. **24** through FIG. **29**.

FIG. **24** through FIG. **27** show a fourteenth aspect of this invention. As shown in FIG. **24**A through FIG. **24**C, the ultrasound transducer array **121** of this aspect comprises a plurality of piezoelectric elements **122** which generate ultrasound and which transmit and receive this ultrasound; a piezoelectric element, positioned on the acoustic radiation surface side of the above plurality of piezoelectric elements **122**, which radiates the ultrasound generated by the above plurality of piezoelectric elements **122**; an acoustic lens **124**, positioned further on the acoustic radiation surface side than the above piezoelectric element **123**; and a backing member **125**, positioned on the back side of the above plurality of piezoelectric elements **122**, as a back load member to absorb unnecessary ultrasound. In this ultrasound transducer array **121**, the above plurality of piezoelectric elements **122** are configured to form at least a one-dimensional array.

The above piezoelectric elements **122** are formed from, for example, soft lead zirconate titanate, $Pb(Zr,Ti)O_3$, or other PZT-system piezoelectric ceramic material, with electrodes formed on both surfaces. The above acoustic lens **124** is formed from silicone resin. The above piezoelectric element **123** is configured from, for example, a first piezoelectric element **123***a* formed from an epoxy resin with alumina as a filler on the acoustic radiation surface side of the piezoelectric elements **122**, and a second piezoelectric element **123***b* formed from an uncombined epoxy resin, further on the acoustic radiation surface side further than the first piezoelectric element **123***a*.

The above backing member **125** is formed from urethane with alumina as a filler. The above piezoelectric elements **122** are connected on the signal line side by a flexible printed board **126** on which a pattern **126***a* is formed; the grounds on the sides of the above first and second piezoelectric elements **123***a*, **123***b* are connected by solder or conductive adhesive using a ground line **127** as a common connection, and covered by a protective resin **128**. As the ground line **127**, a conductive wire or foil is used.

The 3 MHz ultrasound transducer array **121** of this aspect is manufactured by the following method.

First, a 250 μm thin sheet for the first piezoelectric element **123***a* (with acoustic impedance approximately 7.5 MRayl) is ground. Then, one surface of the first piezoelectric element **123***a* is masked with tape or similar, and the second piezoelectric element **123***b* is formed to a thickness of 190 μm on the unmasked surface.

Next, a piezoelectric element **122** approximately 500 μm thick is fixed with adhesive to the above first piezoelectric element **123***a*, and a flexible printed board **126** is joined with solder to the above piezoelectric elements **122**.

Following this, backing material **125** is poured onto and joined with the back side of the above plurality of piezoelectric elements **122**, and wax is used to fix the assembly onto a base, or tape is used to fix it in place. In this state, cutting is performed from the side of the above piezoelectric elements **122**, to form the ultrasound transducer array.

In performing cutting, a precision cutting machine is employed, using a 60 μm thick blade, and cutting at a pitch of 0.3 mm. At this time, the ratio w/t of the width in the array direction of the above piezoelectric elements **122** to the thickness t of a single piezoelectric element **122** in the acoustic radiation axis direction is w/t=0.48.

After cutting, lead wires and solder are used for joining to the surface electrodes on the piezoelectric element **123** side of the piezoelectric elements **122** to make a common GND electrode. Finally, the acoustic lens **124** is formed from silicone resin, to obtain the transducer.

Upon varying the ratio w/t of the width w in the array direction of the piezoelectric elements **122** to the thickness t of the above piezoelectric elements **122** in the acoustic radiation axis direction, impedance curve such as those shown in FIG. **25**A to FIG. **25**D, and in FIG. **26**A to FIG. **26**C, are obtained.

FIG. **25**A to FIG. **25**D, and FIG. **26**A to FIG. **26**C, are graphs showing the impedance curve (acoustic impedance and phase versus frequency) when the ratio w/t of the width w to the thickness t of the piezoelectric elements **122** is varied.

Here, FIG. **25**A is a graph showing the impedance curve when w/t=0.2; FIG. **25**B is a graph showing the impedance curve when w/t=0.3; FIG. **25**C is a graph showing the impedance curve when w/t=0.5; and FIG. **25**D is a graph showing the impedance curve when w/t=0.6. Further, FIG. **26**A is a graph showing the vicinity of the fundamental resonance for w/t=0.5; FIG. **26**B is a graph showing the vicinity of the fundamental resonance for w/t=0.6; and FIG. **26**C is a graph showing the vicinity of the fundamental resonance for w/t=0.8.

The phase is the phase difference between the current and the voltage of the driving signal driving the piezoelectric elements **122**. The magnitude of the acoustic impedance is minimum at the point where this phase difference is zero, at which all the electrical energy supplied to the piezoelectric elements **122** is being converted into vibrational energy.

When w/t<0.3, transverse-direction vibration modes are small, but thickness-direction higher-order vibrations are increased. More specifically, at w/t=0.2 third- and higher-order harmonics are larger, and as w/t is increased, higher-order mode vibrations diminish.

On the other hand, when w/t>0.6, a vibration component occurs in lateral directions perpendicular to the polarization axis of the piezoelectric elements **122**. Consequently when an ultrasound transducer array **121** is configured using piezoelectric elements **122** with w/t>0.6, unwanted vibration modes appear. Hence a problem similar to the above-described harmonic components arises, and cross talk and pulse widths are increased, so that image accuracy is worsened during imaging.

FIG. **27**A through FIG. **27**D show graphs of the echo waveforms and spectrums of ultrasound transducer arrays **121** similarly fabricated using 5 MHz piezoelectric elements **122**, with the ratio w/t of the width w to the thickness t of the piezoelectric elements **122** varied, and measured using a flat stainless steel reflecting sheet.

Here, FIG. **27**A shows the echo waveform and spectrum for w/t=0.2; FIG. **27**B shows the echo waveform and spec-

trum for w/t=0.25; FIG. 27C shows the echo waveform and spectrum for w/t=0.3; and FIG. 27D shows the echo waveform and spectrum for w/t=0.5.

For example, when w/t<0.25 as shown in FIG. 27A and FIG. 27B, large harmonic components appear in the echo waveform, and the waveform is disturbed. It is difficult to completely eliminate these harmonic components even when using a bandpass filter.

On the other hand, as shown in FIG. 27C and FIG. 27D, when w/t=0.3 and w/t=0.5, the harmonic components appearing in the echo waveform are extremely small, and there is no disturbance of the waveform.

From these results it is found that in order to efficiently vibrate the piezoelectric elements **122** and suppress higher-order modes and transverse-direction vibrations, the ratio w/t of the width w in the array direction of the piezoelectric elements **122** to the thickness t of the above piezoelectric elements **122** in the acoustic radiation axis direction must be set within $0.3 \leq w/t \leq 0.5$.

In this aspect, the ratio w/t of the width w of piezoelectric elements **122** in the array direction to the thickness t of the above piezoelectric elements in the acoustic radiation axis direction is set to 0.3 to 0.5, and, in the case of soft PZT-system materials, preferably to w/t=0.4 to 0.5 in order to more effectively suppress higher-order vibration modes.

By setting the w/t ratio of piezoelectric elements **122** to 0.3 to 0.5, and preferably to an optimal value of 0.4 to 0.5, higher-order vibration modes, transverse-direction vibration modes, and other unwanted vibration modes are suppressed, only a simple filter is necessary for imaging, energy losses are reduced, and high-sensitivity piezoelectric elements **122** can be realized inexpensively.

In this aspect, an ultrasound transducer array **121** arranged linearly was described; however, the plurality of piezoelectric elements **122** may be curved in a divided manner, to apply this invention to a convex-type ultrasound transducer array.

FIG. **28** shows a fifteenth aspect of this invention.

In the above-described fourteenth aspect, an ultrasound transducer array **121** is configured by forming a first piezoelectric element **123***a* from epoxy resin using alumina as a filler; in this aspect, the first piezoelectric element **123***a* is formed from carbon to configure the ultrasound transducer array **121**. Otherwise the configuration is substantially the same as that of the above fourteenth aspect, and an explanation is omitted; similar constituent components are assigned the same symbols in the explanation.

As shown in FIG. **28**, the ultrasound transducer array **130** of this aspect is configured having a first matching layer **131** formed from a carbon composite containing ultra-fine particles of silicon carbide (SiC) and boron carbide (B_4C) on the acoustic radiation surface side of the piezoelectric element **122**.

The 5 MHz ultrasound transducer array of this invention is manufactured by the following method.

First, the carbon composite material which is to become the first matching layer **131**, prepared containing ultra-fine particles of silicon carbide (SiC) and boron carbide (B_4C), is ground to a thickness of 200 μm. Here the carbon composite material is graphite (carbon) containing fine particles of SiC and B_4C. This carbon composite material has wedge-shape fine ceramic particles intermixed between grains of the above graphite (carbon) to suppress the growth of microcracks and greatly increase strength compared with graphite. Consequently, even when machined to a thin shape (under 100 μm) for use at still higher frequencies of 10 MHz or higher, this carbon composite material can be machined comparatively easily by using a two-sided lapping machine and using wax, water-soluble adhesive or similar to affix the material to a base for grinding and polishing.

The carbon composite material used in this aspect contains SiC with an average grain diameter 0.5 μm at a mass fraction of 6 wt %, B_4C with an average grain diameter of 5 μm at a mass fraction of 9 wt %, and 4 wt % zirconium boride. The acoustic impedance of this carbon composite material is approximately 8.5 MRayl.

Next, one side of the first matching layer **131** formed from this carbon composite material is masked with tape or similar, and a resin layer 100 μm thick is formed from epoxy resin on the unmasked side to form the second piezoelectric element **123***b*. Then, a piezoelectric element **122**, approximately 300 μm thick, is fixed with adhesive to the above first matching layer **131**, and a flexible printed board **126** provided with a pattern is joined with solder to the piezoelectric element **122**.

Thereafter, wax is used to fix to a base, or tape is used to fix in place, the layered member. In this state, cutting is performed from the side of the above piezoelectric element **122** to midway through the second piezoelectric element **123***b*, to form the ultrasound transducer array.

In this cutting, a precision cutting machine is used, employing a 30 μm thick blade, cutting at a pitch of 130 μm. At this time, the ratio w/t of the width w in the array direction of one piezoelectric element **122** to the thickness t of the piezoelectric element **122** in the acoustic radiation axis direction is w/t=0.33. The ultrasound transducer array of this aspect has a so-called sub-diced configuration, in which two elements are connected in a single pattern.

Next, after a backing material **125** formed from epoxy resin with an alumina filler, used as a back load member, is poured onto and joined with the reverse side of the piezoelectric element **122**, the side surfaces of the above first matching layer **131** are cleaned.

Then, a flexible printed board **132** having a full-coverage electrode is joined to the surface electrode on the side of the piezoelectric element **123** of the piezoelectric element **122** using conductive adhesive, for use as a common GND electrode. Finally, an acoustic lens **124** is formed from silicone resin, to complete fabrication of the transducer.

Similarly to the above-described fourteenth aspect, if the configuration of the transducer of this ultrasound transducer array **130** configured in this way is varied, including the first and second matching layer **131**, **123***b*, the third- and higher-order harmonics are increased for w/t=0.25 or less, and as the w/t ratio is increased, higher-order vibration modes diminish.

If the fabricated ultrasound transducer array **130** has a w/t ratio of 0.25 or less, large harmonic components appear in the echo waveform and cannot easily be eliminated completely even using a band-pass filter.

As shown in FIG. **25**A through FIG. **25**D and FIG. **26**A through FIG. **26**C, when the w/t ratio is 0.6 or higher, vibration components in transverse directions perpendicular to the polarization axis appear, so that when used in an ultrasound transducer array **121**, unwanted vibration modes are present. Consequently a problem similar to that of the above-mentioned high harmonic components arises, and there are increases in cross talk and in pulse widths, so that the image accuracy upon imaging is degraded.

As a result, similarly to the above-described fourteenth aspect, in order that the piezoelectric element **122** vibrates

efficiently, and in order to suppress higher-order modes and transverse-direction vibrations, the ratio w/t of the width w of the piezoelectric element **122** in the array direction to the thickness t of the above piezoelectric element **122** in the acoustic radiation axis direction must be set in the range $0.3 \leq w/t \leq 0.5$.

In this aspect, similarly to the above-described fourteenth aspect, the ratio w/t of the width w of piezoelectric elements **122** in the array direction to the thickness t of the above piezoelectric elements in the acoustic radiation axis direction is set to 0.3 to 0.5, and, in the case of soft PZT-system materials, preferably to w/t=0.4 to 0.5 in order to more effectively suppress higher-order vibration modes.

By this means, advantageous results similar to those of the ultrasound transducer array **121** of the above-described fourteenth aspect can be obtained from the ultrasound transducer array **130** of this aspect.

Because the first matching layer **131** formed from the above carbon composite material is conductive, in addition to functioning as a matching layer, it can also be used as an electrode from the piezoelectric element **122**.

In this aspect, the piezoelectric element **122** and the first matching layer **131** are electrically connected via a thin adhesive layer, and by connecting wires to this first matching layer **131**, a common electrode for the piezoelectric elements **122** after cutting is formed. Also, the exposed side-surface electrode of the piezoelectric element **122** has more area available for wiring than the side surface of the above first matching layer **131**, so that wiring reliability is improved. Further, in a configuration in which wiring is performed from the side surface of the first matching layer **131**, the acoustic radiation area can be made large with respect to the size of the transducer, so that the device size can be easily reduced.

Though not shown in FIG. **28**, the signal electrode side of the piezoelectric element **122** and the flexible printed board **132** which serves as the common GND electrode must be insulated. As the method of insulation, a method is used in which a polyimide insulator is positioned in the portion neighboring the piezoelectric element **122** of the flexible printed board **132** itself. Other possible insulation methods are available not by providing a full-surface electrode on the piezoelectric element **122** but by providing a portion without an electrode in the region neighboring the flexible printed board **132**, or by sealing the exposed signal electrode of the piezoelectric element **122** with resin or similar means.

FIG. **29** shows the ultrasound transducer array of a sixteenth aspect of the invention. This aspect is a modification of FIG. **28**; in the ultrasound transducer array **140** shown in the figure, first and second matching layers **131**, **123*b*** are layered as shown in FIG. **28**, and are joined to a piezoelectric element **141** which is somewhat smaller than these first and second matching layers **131**, **123*b***.

Then, wax is used to fix to a base, or tape is used to fix in place, the layered member. In this state, cutting is performed from the side of the above piezoelectric element **141** to midway through the second piezoelectric element **123*b***, to form the ultrasound transducer array in which the w/t ratio is 0.3 to 0.5, and preferably an optimal value of 0.4 to 0.5.

After cutting, the divided first matching layer **131** is connected using copper wires **129** and conductive resin **142**, and the signal-line is connected by solder to each piezoelectric element **141** using fine wires **144** from substantially the distal end of the glass-epoxy board **143** with patterns formed on both sides.

A framework, not shown, is provided on both ends of the above first matching layer **131**, and a groove portion formed is filled with backing material **125** to form the back load member, and in addition the acoustic lens **124** is formed from silicone resin to fabricate the transducer.

Advantageous results similar to those of the above-described fourteenth and fifteenth aspects are obtained from the ultrasound transducer array **140** configured in this way, and in cases where wiring is difficult from the side surface of the first matching layer **131**, which is made thin for operation at higher frequencies, wiring operations are made easy, and manufacturing yields are improved.

In this variant, the first and second matching layers **131**, **123*b*** are layered, and are joined to a piezoelectric element **141** somewhat smaller than these first and second matching layers **131**, **123*b*** to form a layered member, after which, by cutting to a depth such that a portion of the cut reaches the first matching layer **131**, a region for ground wiring is formed. Then, dicing is performed to form the array elements, and by connecting wires **129** using conductive resin **142** a common electrode is formed, to fabricate the ultrasound transducer array **140**. After bonding, wiring is performed in portions at the cut in the carbon material, so that there are no conduction faults due to adhesive, and manufacturing yields and reliability are improved.

In this aspect, the first matching layer **131** is cut completely through; however, by leaving a slight amount in the depth direction, or by providing a remaining portion at an edge, there is no need to connect a common ground to each piezoelectric element after cutting, so that an array can be fabricated inexpensively and with high reliability. Further, by cutting through 80% or more of the piezoelectric element **141** in the depth direction, piezoelectric elements **141** can be fabricated with a high electromechanical transduction efficiency, regardless of the presence of the first matching layer **131**.

Because after cutting the neighboring piezoelectric elements **141** are connected, the problem of cross talk arises. However, by leaving material on the common GND electrode side, the need for wiring is eliminated, and the transducer can be manufactured inexpensively. And by cutting into only the sub-diced portion to midway through the piezoelectric element **141**, or to midway through the first matching layer **131**, which is a conductive matching layer, cross talk can be suppressed and wiring reliability improved.

Similarly to the fourteenth aspect, by curving the array in a state in which a plurality of piezoelectric elements **141** are separated, a convex-shape ultrasound transducer array can be manufactured.

Various variants of each of the configurations of the above-described fourteenth through sixteenth aspects are conceivable; representative examples of these are indicated below.

In addition to PZT-system piezoelectric ceramics and other PMN-system piezoelectric ceramics obtained by ordinary sintering, similar advantageous results can be obtained by using materials such as piezoelectric single crystals as the piezoelectric element **141**.

The method of manufacture of transducers is not limited to only those of the above-described aspects; for example, a second piezoelectric element **123*b*** using epoxy resin may be ground and shaped to a prescribed thickness, a first piezoelectric element **123*a*** formed by pouring an epoxy resin with alumina filler, then grinding and shaping, and after fixing in place the piezoelectric element **141** using an adhesive, dicing is performed from the side of the piezoelectric element **141** to midway through the second piezoelectric element **123*b***, such that the w/t ratio is from 0.3 to 0.5.

Compared with such a backing member **125** as a back load member, by forming a hard piezoelectric element **123** and then cutting from the side of the piezoelectric element **141**, the precision in the depth direction is improved, there is little vibration in the piezoelectric element **141** during cutting, chipping and other problems tend not to occur, and groove widths are stable. Consequently the width of the piezoelectric elements **141** can be reduced for use at high frequencies, and sizes can be reduced, to manufacture transducers with good yields.

As explained using FIG. **29**, a framework, not shown, is provided after wiring signal-side, and an epoxy resin, which remains flexible after hardening, intermixed with alumina, zirconia or similar insulating powder is poured into the framework to form the backing member **125** as a back load member; by this means, an adhesive layer is not necessary, scattering in reflections at interfaces is small, and stable transducers can be formed. Of course each of the configurations of the aspects here described can be variously modified and altered.

This invention is not limited only to the above aspects; if the width w in the array direction of the above piezoelectric element **141** is the width w perpendicular to the acoustic radiation axis of the above piezoelectric element **141**, an ultrasound transducer array **140** may also be configured in which the ratio of the width w perpendicular to the acoustic radiation axis of the above piezoelectric element **141** to the thickness t of the above piezoelectric element **141** in the acoustic radiation axis direction is from 0.3 to 0.5, and more preferably from 0.4 to 0.5.

Having described the preferred embodiments of the invention referring to the accompanying drawings, it should be understood that the present invention is not limited to those precise embodiments, and that various changes and modifications thereof could be made by one skilled in the art without departing from the spirit or scope of the invention as defined in the appended claims.

As explained above, in this invention divided grooves are formed to a depth such that piezoelectric elements are separated, reaching the matching layer, and the thickness of remaining material in the matching layer is made small, such that cross talk can be sufficiently suppressed, and filler material can be used to prevent a reduction in the strength.

What is claimed is:

1. An ultrasound transducer array, in which a plurality of piezoelectric elements, which can be electrically operated independently, are arranged in an array, and comprising:

- one or a plurality of matching layers, provided on the acoustic radiation surface side of said piezoelectric elements;
- a conductive material layer, provided on the side of said matching layer joined with said piezoelectric elements, in the direction along the array direction, a portion of which is in contact with and electrically connected to said piezoelectric elements along said array direction, and a portion of which is not in contact with said piezoelectric elements along said array direction;
- a plurality of grooves, which mechanically and electrically insulate said piezoelectric elements and at least a portion of said matching layer for each electrically independently operable element; and, conductive material, which fills at least a part of the portions of said grooves formed where said piezoelectric elements and said conductive material layer are not in contact.

2. The ultrasound transducer array according to claim **1**, wherein said conductive material layer is formed from a first thermosetting base resin, and said conductive material used for filling is formed from a second thermosetting base resin.

3. The ultrasound transducer array according to claim **2**, wherein said first thermosetting base resin and said second thermosetting base resin are the same.

4. The ultrasound transducer array according to claim **2**, wherein, of said matching layer, the layer adjacent to said piezoelectric elements is formed from a carbon composite material containing carbides.

5. The ultrasound transducer array according to claim **4**, wherein said conductive material layer and said filler conductive material are formed from a thermosetting resin intermixed with carbon powder.

6. The ultrasound transducer array according to claim **5**, wherein said carbon powder is a powder of the carbon composite material of said matching layer.

7. The ultrasound transducer array according to claim **2**, having a conductive member which makes a common electrical connection to said plurality of electrically independently operable piezoelectric elements along said array direction, and wherein said conductive member is fixed to said conductive material layer by said filled conductive material.

8. The ultrasound transducer array according to claim **2**, wherein the ratio of the width w in the array direction to the thickness t in the ultrasound radiation direction of said plurality of piezoelectric elements is from 0.3 to 0.5.

9. The ultrasound transducer array according to claim **8**, wherein the ratio of the width w in the array direction to the thickness t in the ultrasound radiation direction of said plurality of piezoelectric elements is from 0.4 to 0.5.

10. The ultrasound transducer array according to claim **1**, wherein, of said matching layers, the layer adjacent to said plurality of piezoelectric elements is formed from a carbon composite material containing carbides, and also serves as said conductive material layer.

11. The ultrasound transducer array according to claim **10**, wherein said filled conductive material is formed from a thermosetting resin base intermixed with carbon powder.

12. The ultrasound transducer array according to claim **10**, wherein said carbon composite material containing carbides contains, as said carbides, fine powder of silicon carbide or of boron carbide.

13. The ultrasound transducer array according to claim **10**, wherein said carbon composite material containing carbides contains silicon carbide as said carbides, and also contains a fine powder of borides.

14. The ultrasound transducer array according to claim **10**, having a conductive member which makes a common electrical connection to said plurality of electrically independently operable piezoelectric elements along said array direction, and wherein said conductive member is fixed to said conductive material layer by said filled conductive material.

15. The ultrasound transducer array according to claim **10**, wherein the ratio of the width w in the array direction to the thickness t in the ultrasound radiation direction of said plurality of piezoelectric elements is from 0.3 to 0.5.

16. The ultrasound transducer array according to claim **15**, wherein the ratio of the width w in the array direction to the thickness t in the ultrasound radiation direction of said plurality of piezoelectric elements is from 0.4 to 0.5.

17. The ultrasound transducer array according to claim **1**, having a conductive member which makes a common electrical connection to said plurality of electrically independently operable piezoelectric elements along said array direction, and wherein said conductive member is fixed to said conductive material layer by said filled conductive material.

18. The ultrasound transducer array according to claim **17**, wherein said conductive member is a conductive material formed into any of those among a wire shape, ribbon shape, rod shape, or foil shape.

19. The ultrasound transducer array according to claim **17**, wherein the ratio of the width w in the array direction to the thickness t in the ultrasound radiation direction of said plurality of piezoelectric elements is from 0.3 to 0.5.

20. The ultrasound transducer array according to claim **19**, wherein the ratio of the width w in the array direction to the thickness t in the ultrasound radiation direction of said plurality of piezoelectric elements is from 0.4 to 0.5.

21. The ultrasound transducer array according to claim **1**, wherein the ratio of the width w in the array direction to the thickness t in the ultrasound radiation direction of said plurality of piezoelectric elements is from 0.3 to 0.5.

22. The ultrasound transducer array according to claim **21**, wherein the ratio of the width w in the array direction to the thickness t in the ultrasound radiation direction of said plurality of piezoelectric elements is from 0.4 to 0.5.

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